



THE BOOK OF
WIRELESS
TELEGRAPH & TELEPHONE

A. FREDERICK COLLINS

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**THE BOOK OF WIRELESS
TELEGRAPH AND TELEPHONE**

By A. Frederick Collins

**The Book of Wireless Telegraph and
Telephone**

The Book of Stars

The Book of Magic

The Book of Electricity

Gas, Gasoline and Oil Engines

The Amateur Chemist

The Amateur Mechanic

How to Fly

The Home Handy Book

Keeping Up With Your Motor Car

Motor Car Starting and Lighting

D. APPLETON AND COMPANY
Publishers **New York**

THE BOOK OF WIRELESS TELEGRAPH AND TELEPHONE

*BEING A CLEAR DESCRIPTION OF WIRELESS TELEGRAPH AND
TELEPHONE SETS AND HOW TO MAKE AND OPERATE
THEM, TOGETHER WITH A SIMPLE EXPLANA-
TION OF HOW WIRELESS WORKS*

BY
A. FREDERICK COLLINS

INVENTOR OF THE WIRELESS TELEPHONE

AUTHOR OF "WIRELESS TELEGRAPHY, ITS HISTORY, THEORY AND
PRACTICE, DESIGN AND CONSTRUCTION OF INDUCTION
COILS," "BOOK OF ELECTRICITY," ETC.



FULLY ILLUSTRATED

**D. APPLETON AND COMPANY
NEW YORK : : 1922 : : LONDON**

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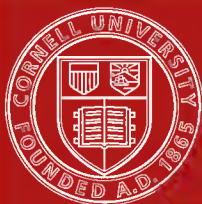
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TO
OSCAR A. DE LONG, JR.
a MAKER OF GOOD WIRELESS THINGS



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A WORD TO THE BOY

Wireless is a thrilling pastime.

Fancy a boy sitting in his room at home with his fingers on a telegraph key and a telephone receiver to his ear *listening-in* to the news of the world as it is flashed out from the great coast stations or by ships far out at sea! It's a great experience.

Yet thousands of boys are doing this wonderful thing every day and night of the year, and you, my young friend, can do it as easily as they, for any boy can own a real wireless station, if he really wants to.

If you have sharp eyes, you will see everywhere you go webs of wire spun from the housetops and barnables, or spanning backyards, and often frontyards, too. These wires are not clothes lines; no, indeed! They have a far higher and, I should say, as useful a purpose as clothes lines, for they are *wireless wires*.

These wires are called *aerials* by wireless operators. The word *aerial* may sound a little hard at first, and there are some other words used in wireless that are hard for the outsider, but they get to be very common words to the boy who puts up his own station, for there is no lesson so easily learned as the one taught by the thing itself, and no school like that of doing things yourself. Some of these aerials have a stretch of only twenty to thirty feet of wire, while others have upwards of 1,000 feet, the amount depending on the place, the pocket-book and the boy.

But you don't need to spend a lot of money to put up a good wireless station, for I have many boy friends who made all the apparatus they use, except the telephone receiver, and their stations work as well as those of some others I know who bought their outfits ready for use.

To be a wireless boy and make your own apparatus is to have the kind of stuff in you of which successful men are made—men who, if they were shipwrecked on a desert isle at daybreak, would have something to eat by noon, a spring bed to sleep on by night and a wireless station the next day sending out S O S to ships below the horizon, for help.

In nearly every city there is an electrical supply store where you can get all of the different parts named in this book. If you live in a place where there is no dealer, then write to the Manhattan Electrical Supply Co., 17 Park Place, New York City; the J. H. Bunnell Co., 32 Park Place, New York City; and the International Brass and Electric Co., 176 Beekman Street, New York City, and they will quote you prices.

For continuous wave telegraph and telephone sending and receiving apparatus write the Radio Corporation of America, Woolworth Building, New York City.

A. FREDERICK COLLINS,
"The Antlers," Congers, New York.

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THE BOOK OF WIRELESS EGRAPH AND TELEPHONE

PART I

A DEMONSTRATION WIRELESS OUTFIT

CHAPTER I

THE SENDER

Before trying to make a wireless telegraph outfit to send and receive messages over long distances, it is better for a beginner to put up a small set first and learn how to work it and how it works.

The very first thing to do is to get all of the parts of the *sender* and the *receiver*; connect them together, and put up an *aërial*. The next step is to learn the *wireless code*, that is how to use a telegraph key to make the dots and dashes which represent the letters of the alphabet and then—practice awhile.

When you can send and receive five or ten words a minute it is time to get a larger set and when you are ready for a larger set, a larger set will no doubt be ready for you.

All of the parts of the sets described in this book may be bought of dealers in electrical supplies, or they may be made at home. For the beginner it is, perhaps, better to buy certain parts ready made, especially the spark-coil, as the results will be surer.

If, on the other hand, you want to make the parts of either of the sets described, drawings will be found with the sizes marked on them and if you will but follow as well as you can the simple directions which I have given you cannot go wrong. So now get busy.

Every wireless *station* is made up of three distinct parts:

- (1) A sender, also called a *transmitter*,
- (2) A receiver, also called a *receptor*, and
- (3) An aerial wire, also called an *antenna*, and a ground.

The sender will be described in this chapter.

There are four separate pieces of apparatus which go to make up this sender, and which with a suitable *aerial* and *ground*, will send messages over a distance of a quarter to half a mile.

These pieces of apparatus are:

- (1) A *battery*, for producing a current of electricity,
- (2) A *telegraph key*, for making and breaking up the battery current into *dots* and *dashes*,
- (3) A *spark-coil*, also called an *induction coil*, which

changes the current from the battery into *high pressure electricity*, and

- (4) A *spark-gap*, in which sparks are set up by the high pressure electricity.

The Battery.—A battery for producing a current of electricity is made up of five or six *dry cells* connected together with pieces of copper wire.

A single *dry cell* is shown in Fig. 1. It is made up of a stick of *carbon* set in a tall cup formed of *sheet zinc*, the space in between being filled with a paste which acts upon the carbon and zinc and produces an electric current.

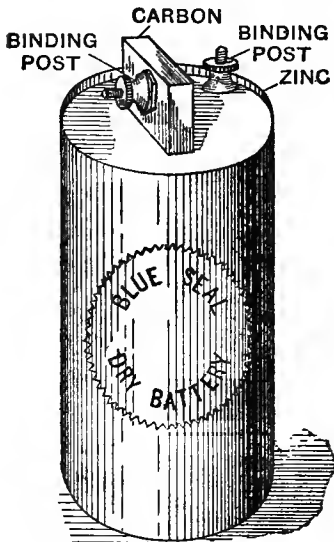


FIG. 1.—A DRY CELL.

Look again at Fig. 1 and you will see that secured to the upper end of the carbon is a *binding post* and that to the upper edge of the zinc cup is fastened another binding post. Binding posts are used to make it easy to connect the ends of wires to the carbon and to the zinc. Fig. 2 shows the kind of binding post that is used on dry cells and is drawn full size.

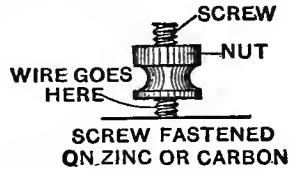


FIG. 2.—BINDING POST USED ON DRY CELLS.

Five or six dry cells when connected together will give enough current to work the *spark-coil*. These cells are connected with each other as shown in Fig. 3, that is the zinc of one cell is connected with the carbon of the next cell by a piece of copper wire about 3 or 4 inches long.

Any kind of copper wire will do for the connections but the kind known as *bell wire*, that is copper wire No. 18 Brown and Sharpe gauge covered with cotton thread and soaked in *paraffin*,

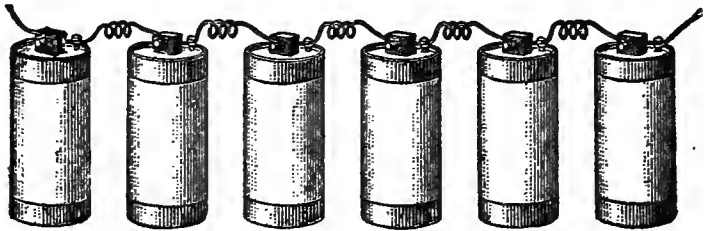


FIG. 3.—A BATTERY OF DRY CELLS.

such as is used for connecting up electric bells, may be bought for 10 or 15 cents a half-pound—about 75 feet—and a half-pound will be enough to connect up both the sender and the receiver.

The Telegraph Key.—This need not be a regular telegraph key, but instead it may be a simple *strap-key* as shown in Fig. 4. A strap-key can be easily made by cutting a piece of *spring sheet brass*, or even tin will do, 4 inches long and $\frac{1}{2}$ inch wide, as shown in Fig. 5, and drilling a hole $\frac{1}{8}$ inch in diameter through

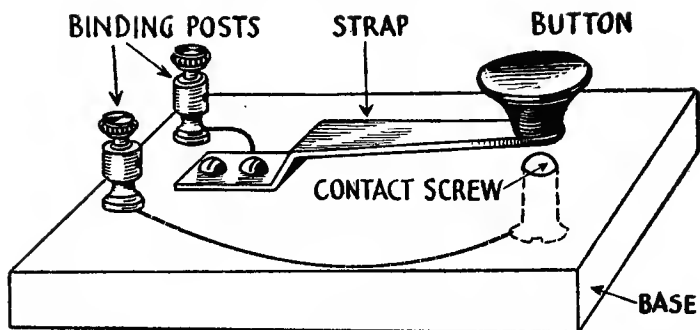


FIG. 4.—THE STRAP KEY COMPLETE.

each end; then bend it at one end as shown in Fig. 6. This piece of brass is called a *strap* and from this comes the name, *strap-key*.

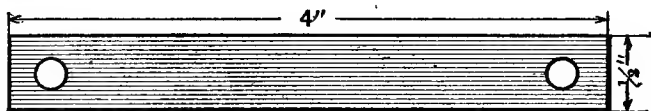


FIG. 5.—BRASS STRAP FOR KEY.

For a button, cut off the head of a clothes-pin and screw it to the long end of the strap with a round-headed screw. Make a wood base $4\frac{1}{2}$ inches long by $2\frac{1}{2}$ inches wide and $\frac{1}{2}$ inch thick

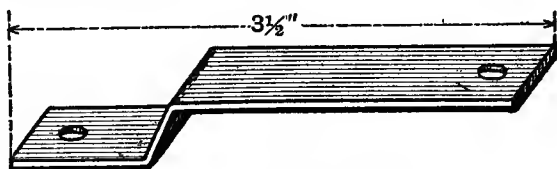


FIG. 6.—BRASS STRAP BENT.

and drill three holes, each $\frac{1}{8}$ inch in diameter, through the base as shown in Fig. 7.

Screw the short end of the strap to the board at the place

marked X so that the screw holding the button and the strap together will be directly over the hole at the other end of the base and which is marked *contact screw*. Put a machine screw having a nut on one end through this hole so that the head of the

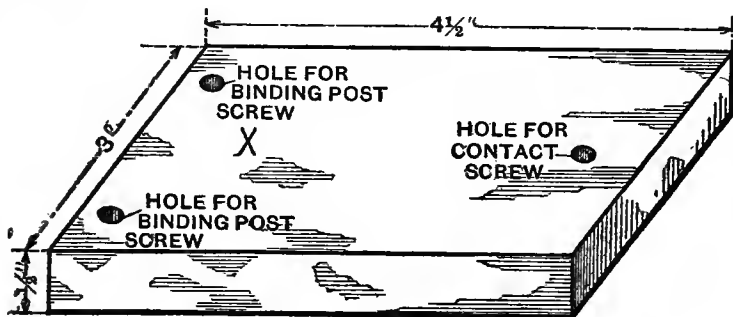


FIG. 7.—THE BASE AS IT LOOKS WHEN FINISHED.

screw is on the bottom and the end sticks through the top of the board about $\frac{3}{16}$ of an inch and then screw on the nut.

Next screw on two binding posts to the back of the board and

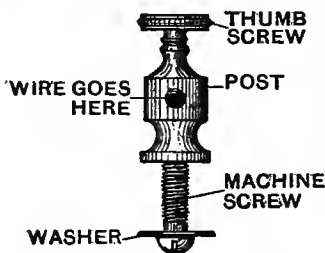


FIG. 8.—BINDING POST USED ON KEY AND SPARK-COIL.



FIG. 9.—WOOD SCREW BINDING POST.

the key is ready to be *wired up*. These binding posts are a little different from those used on dry cells (see Fig. 2) in that they have holes drilled through them so that the ends of the wire can be slipped into the holes and are held tight when screwed down, as shown in Fig. 8 and Fig. 9.

Take some bell wire and connect the strap of the key, by bending one end of a wire around the screw, which holds it to the board, to one of the binding posts; then loop the end of another piece of wire over the screw and under the nut in front and connect with the other binding post. The dotted lines in Fig. 4 show how the key is connected up.

The Spark-Coil.—The *spark-coil*, or *induction coil*, as it is often called, which is used to change the battery current into a

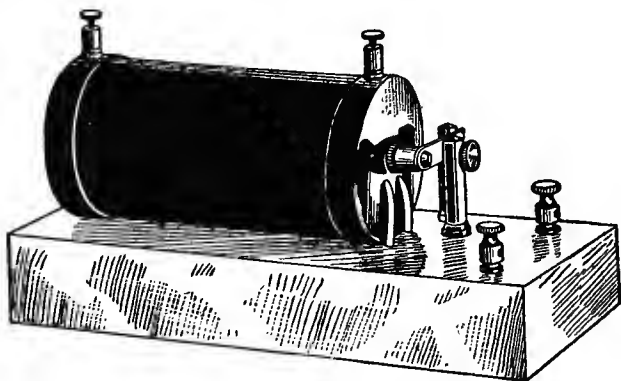


FIG. 10.—THE SPARK-COIL COMPLETE.

current of *high pressure* to make *jump sparks* is shown in Fig. 10.

The coil, it will be seen, is *mounted* on top of a polished wood base, and is covered with a thin sheet of hard rubber or bookbinder's cloth. On top of the base at one end of the coil is mounted an *interruptor*—a device which makes and breaks the battery current several hundred times a minute. A full-sized view of the *interruptor* is shown separately in Fig. 11.

Also at the right-hand end of the top of the base are two large binding posts, one for connecting in the wire from the battery and the other for connecting in the key.

Now every spark-coil, or induction coil, is formed of a little roll of soft iron wires, called a *core*, and around this core is

wound two or three layers of rather thick, *insulated* copper wire, that is wire that is covered with cotton thread; this coil of wire is called the *primary coil* and the ends of this coil are connected to the large binding posts on the base through the *interruptor*.

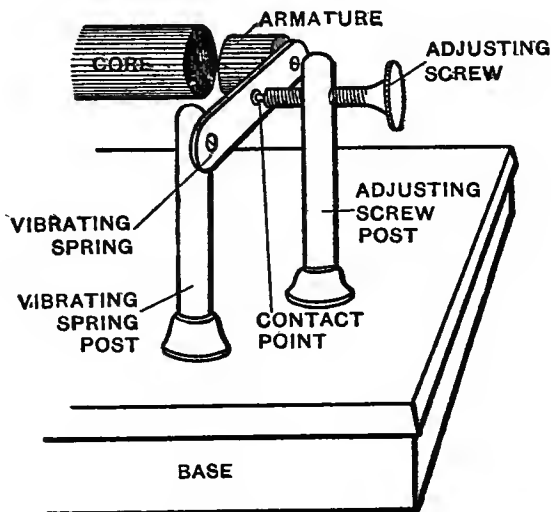


FIG. 11.—INTERRUPTOR OF SPARK-COIL.

Around the *primary coil* is wound another coil of very fine *insulated* copper wire called the *secondary coil*. A glance at Fig. 10 shows another pair of binding posts on top of the coil. The ends of the *secondary coil*, in which the *high pressure* currents are *set up* by the current from the battery, are connected with these binding posts.

The *spark-coil* shown in Fig. 10 is about 8 inches long, 4 inches wide and 5 inches high. When the coil is connected with a battery and two wires are screwed into the upper binding posts and the ends of these wires are drawn half an inch apart a bright, crackling spark will jump across the gap thus formed, and this is called a *spark-gap*.

The Spark-Gap.—The spark is a very important thing in

wireless telegraphy, in fact the distance over which messages can be sent depends very largely upon the length and the kind of spark a coil gives. A thin, red spark has very little sending power, but a *fat*, snappy spark will send over long distances if the *aërial* and *ground* wires are right.

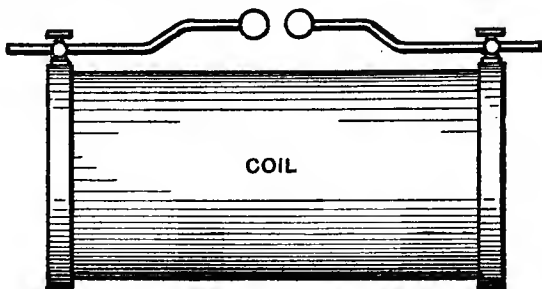


FIG. 12.—SPARK-GAP ON THE COIL.

For sending wireless messages a spark-gap formed of a pair of brass balls, or any other metal such as copper or zinc, and having a diameter of $\frac{3}{8}$ inch or larger, is needed. Pieces of stiff brass wire 4 inches long and which will slip through the holes of the binding posts as shown in Fig. 12, must be screwed in,



FIG. 13.—SPARK-GAP MADE OF ZINC ROD.

or soldered to the brass balls. The wires are bent up to keep the spark away from the coil.

I do not know of any maker of spark-coils who supply coils with spark-gap balls fitted to them. If brass balls are hard to get, or cost too much, another way to make a spark-gap is to cut off two pieces of brass or zinc rod having a diameter of at least $\frac{3}{8}$ inch, and have each piece $\frac{1}{2}$ inch long. Round the edges

off with a file and screw in, or solder on, the brass wires as shown in Fig. 13.

This ends all the work to make the spark-coil complete, and all that remains to be done is to wire up the different parts and connect the spark-coil with the *aërial* and *ground* wire.

Connecting up the Parts.—Before connecting up the sender, the parts should be placed on the table or bench which is to be used for operating. The key should be placed on the right-hand corner nearest the operator; the battery near the right-hand corner away from the operator and the spark-coil a little to the left of the key and between the key and the battery.

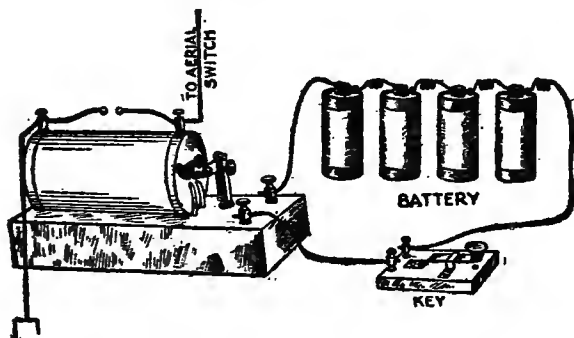


FIG. 14.—HOW THE SENDER IS CONNECTED UP

The purpose of this plan is to have the key in the handiest position for the operator, the battery out of the way and the spark-coil where the *adjusting screw* of the interruptor is within easy reach.

One of the wires of the battery is connected with one of the binding posts on the base of the spark-coil, and the other wire of the battery is connected with one of the binding posts of the key, while the other binding post of the key and remaining binding post of the spark-coil are connected together, all of which is clearly shown in the outline drawing, Fig. 14.

After the aërial wire is put up it is connected with one of

the *spark-gap binding posts* while the other *spark-gap binding post* must be connected with a sheet of zinc, or of copper, buried in the earth, or if a water- or a gas-pipe is at hand the ground wire can be soldered to it as explained in Chapter III under the heading of *Aërial Wires and Grounds*.

Adjusting the Sender.—Two *adjustments* will have to be made before messages can be sent and both of these are on the spark-coil.

First set the spark-gap balls a half inch apart and then turn the *adjusting screw* of the *interruptor*, which is shown in Fig. 10 to the *right* until the *contact point* just touches the *vibrating spring* of the *interruptor*.

Now press down the button of the key and if the *interruptor* is in adjustment a stream of sparks will jump between the brass balls of the spark-gap. Turn the *adjusting screw* of the *interruptor* a little at a time until the sparks are white and crack clear and sharp. This done set the spark-gap balls so that they are only $\frac{1}{8}$ inch apart. The sender is now in adjustment and ready for operation.

All through this chapter I have told you what to do but there is one thing I must caution you not to do, and that is not to hold down the strap of the sending key any longer than it takes to make a dot or a dash. If you do not heed this warning your battery of dry cells will soon *run down* and you will have to buy new ones or else close up shop.

COST OF SENDER WHEN BOUGHT OF DEALERS

6 Dry cells at 20c.	\$1.20
Nickel-plated strap-key .....	.50
Bell wire .....	.10
Spark-coil, $\frac{1}{2}$ -inch spark.	6.00
Brass balls, per pair, $\frac{1}{2}$ -inch diameter. ....	.50
Attaching brass rods to brass balls. ....	.25
<hr/>	
Total	\$8.55

COST OF MATERIALS TO MAKE SENDER

6 Dry cells at 20c.....	\$1.20
Strap-key, brass, 10c; screws, 5c; 2 binding posts, 10c .....	.25
Bell wire, 50 to 75 feet.....	.10
Spark-coil, $\frac{1}{2}$ -inch spark.....	
Interruptor	1.00
Secondary wire No. 32, Brown & Sharpe gauge.....	1.50
Primary wire No. 16, Brown & Sharpe gauge.....	.25
Iron wire for coil.....	.10
Tin foil for condenser.....	.20
Brass rod for spark-gap.....	.10
Attaching brass rod to brass balls.....	.25
4 Binding posts.....	.25
Shellac varnish .....	.10
Total	\$5.30

CHAPTER II

THE RECEIVER

A wireless telegraph receiver is a very simple affair and, with the exception of the *telephone receiver* which you will have to buy, the whole thing can be easily made and at a very small cost.

The receiver I shall describe in this chapter will receive messages over far longer distances than the sender you have just made will send. In fact, it is much easier to make a receiver which will receive messages over long distances than it is to make a sender which will send over equal distances. Usually, when you have made your receiver and connected it up with your aërial, you will find there is a *high power station* somewhere within your range.

There are four parts to this receiver, and with an aërial wire that is high enough and long enough, messages may be received from stations of from ten to fifty miles away, the distance, of course, depending largely upon the adjustment of your *detector*, and the power of the station that is sending.

The various pieces of apparatus are:

- (1) A *dry cell*, for providing a current of electricity,
- (2) A *switch*, for cutting off the current from the dry cell when the receiver is not in use,
- (3) A *detector*, for changing the feeble *electric waves*, which strike the aërial wire from the sending station, into stronger electric currents produced by the dry cell, and
- (4) A *telephone receiver* which changes the strong electric currents from the dry cell into *sound waves* so that the ear can hear them as dots and dashes.

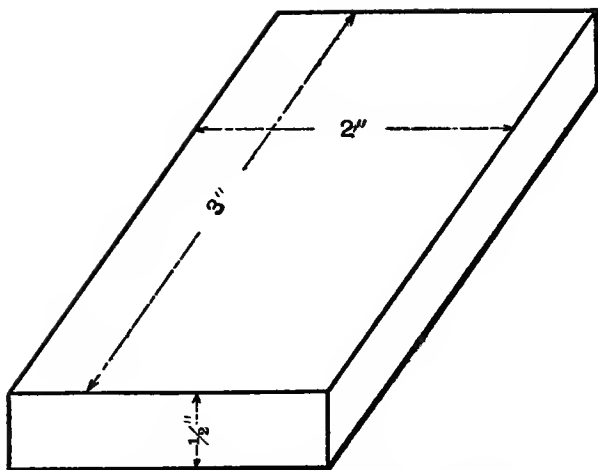


FIG. 15.—BASE OR BLOCK FOR SWITCH.

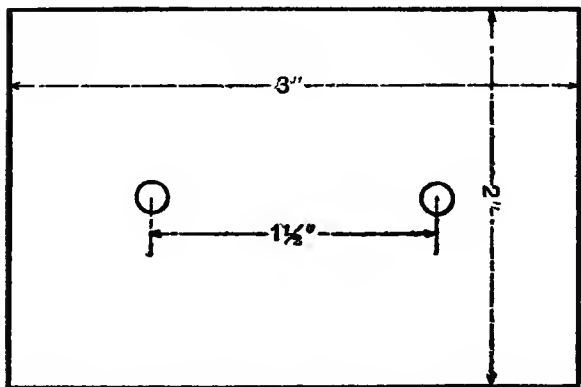


FIG. 16.—TOP OF BASE SHOWING WHERE HOLES ARE DRILLED.

You don't need to bother just now about how the different parts of the receiver work, the main thing is to get the apparatus set up and in working order.

The Dry Cell.—The dry cell is exactly like the one shown in Fig. 1, on page 2; one dry cell will give all the current needed to work the detector and the telephone receiver.

The Switch.—To make a switch, saw out a block of wood

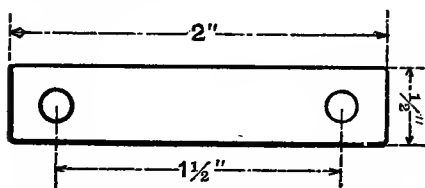


FIG. 17.—CONTACT LEVER SHOWING SIZE AND WHERE HOLES ARE DRILLED.

3 inches long, 2 inches wide and $\frac{1}{8}$ inch thick, as shown in Fig. 15; the next drawing, Fig. 16, shows the top of the board, or base, as it is called. Now drill two holes $\frac{1}{8}$ inch in diameter through the board

$\frac{1}{2}$ inches apart at the places marked with the circles.

In making this base and others for different parts of your wireless apparatus the sharp edges of the wood should be smoothed off with sandpaper as this not only makes the blocks look better but prevents their edges from getting dented. A coat of *shellac varnish* will also give them a more finished appearance.

The next thing to do is to cut a strip of sheet brass $\frac{3}{8}$ inch wide and 2 inches long. This strip is called a *contact lever* for the reason that it makes contact with another part of the switch.

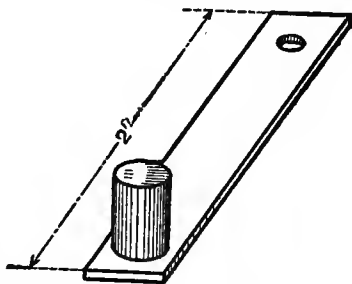


FIG. 18.—CONTACT LEVER WITH HANDLE.

Near the ends of the contact lever and at the places where the circles are drawn in Fig. 17, drill two holes $1\frac{1}{2}$ inches apart; make a little wooden knob or handle about $\frac{3}{8}$ inch in diameter and $\frac{1}{2}$ inch long and screw one end of the contact lever to it

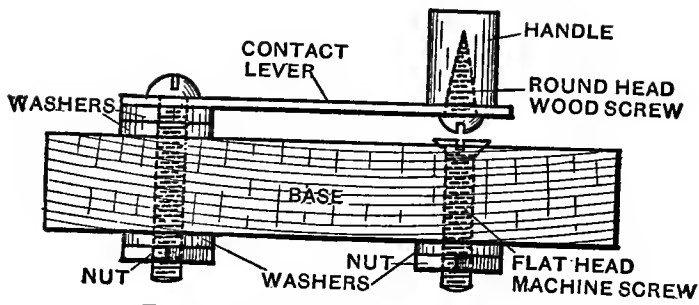


FIG. 19.—CROSS SECTION VIEW OF SWITCH.

with a round-headed brass wood screw; this will leave the round head of the screw projecting from the bottom of the brass lever. The lever with the handle is shown in Fig. 18.

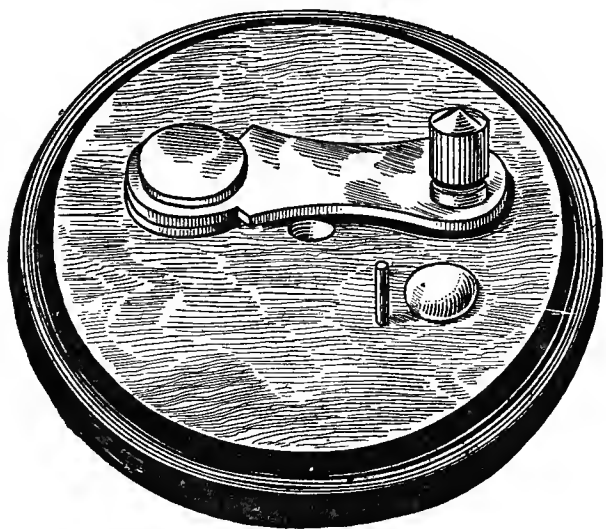


FIG. 20.—SWITCH COMPLETE.

Through the other hole of the lever slip a machine screw 1.1 inch long, put on a couple of brass washers to raise the lever

from the base a little; push the screw through one of the holes in the board; put on another washer, and last of all screw on a nut to keep the lever from working loose, but the lever must move smoothly back and forth.

Through the hole in the base under the handle of the lever put a flat-headed machine screw $\frac{3}{4}$ inch long and screw a nut on underneath the base. Now when the lever is brought to the middle of the base the round head of the screw which holds the lever and the handle together and the flat head of the screw on top of the base will meet exactly and so make contact with each other. A *sectional view* of the switch is shown in Fig. 19.

The switch when it is finished looks a little different from the one shown in Fig. 20, for this is a picture of a switch that was bought ready made; but they work just alike.

A Simple Crystal Detector.—This is called a crystal detector, because a piece of galena, or other crystal, is used for one of the detecting elements. It is shown at *A* and *B* in Fig. 21. Make a base of hard wood $\frac{1}{2}$ inch thick, 2 inches wide, and 3 inches long. Near one end bore a $\frac{1}{2}$ inch hole and near the other end drill a $\frac{1}{8}$ inch hole and screw in a binding post. Around the screw loop a

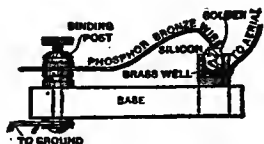


FIG. 21A.—CROSS SECTION OF A SIMPLE CRYSTAL DETECTOR.

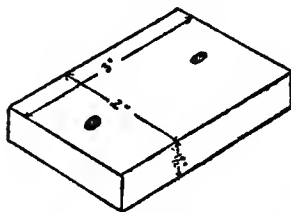


FIG. 21B.—BASE OF DETECTOR.

wire which is to connect with the ground. Cut off a piece of brass rod $\frac{1}{2}$ inch in diameter and 1 inch long and drill a hole in one end $\frac{3}{8}$ inch in diameter and to a depth of $\frac{3}{8}$ inch. Heat the end of the

rod in an alcohol or a gas flame, and run it full of melted solder.¹ Force a bit of silicon or any other sensitive crystal into the solder so that when the solder is cold the silicon will be firmly imbedded in it. Solder a wire to the rod so that it can be connected with the aerial and force the rod down into the hole in the base. Sharpen one end of a piece of phosphor-bronze wire, No. 28 or 30 Brown and Sharpe gauge, about $3\frac{1}{2}$ inches long and bend the wire as shown in the cut; slip the blunt end of the wire through the

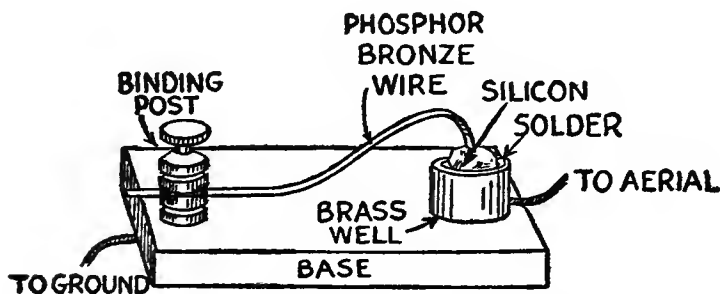


FIG. 22.—THE SIMPLE CRYSTAL DETECTOR COMPLETE.

hole in the binding post. Now adjust the wire until the pointed end presses on the crystal and you will have what is called a *cat-whisker detector*.

A battery is not needed to operate this detector with, as the electric oscillations that are set up in the aerial by the incoming waves supply the current. When a crystal detector is properly adjusted it is quite sensitive. The pointed end of the wire that presses against the crystal must not be too sharp and it must make good contact with the crystal. Besides silicon a large number of other minerals can be used as the sensitive element. *Iron*

¹ *Wood's Metal* is better because it melts at a temperature of boiling water.

pyrites or *fool's gold*, as this kind of crystal is commonly known, makes a good detector, and *galena*, whose chemical name is lead sulfide, is largely used at the present time.

Now take a common steel sewing-needle, about No. 9, and weight it by fastening a lead bullet to the middle of it with a drop of sealing wax and lay it across the leads. (See Appendix F.)

The Telephone Receiver.—While there is not very much to a telephone receiver, yet it is a piece of apparatus that is hard to make, and especially one good enough to use for wireless work. It requires a skilled workman and fine machine tools to make one *good enough* for even this small set. I shall not, therefore, encourage you, whether you are a beginner or an expert operator, to try to make your own telephone receiver, but it is well to know the names of the different parts which form it. How it works will be told in Chapter V.

A telephone receiver is formed of five chief parts, and these are:

- (1) A thin, round piece of sheet iron called a *disk*, or *diaphragm*,
- (2) A small *electromagnet*, made of a magnetized steel bar and wound with very fine silk-covered copper wire,
- (3) A metal *case* which holds the electromagnet in place,
- (4) A *cover*, having a small hole in it and which screws on to the case and holds the iron disk, or diaphragm, in place, and
- (5) A *telephone cord*, that is a pair of very flexible insulated wires bound together.

Each part of the telephone receiver, except the *telephone cord*, is shown separately in Fig. 23, and the receiver is shown put together in Fig. 24. The *telephone cord* is shown in Fig. 25.

The *magnet* is screwed to the bottom of the case and the ends of the fine wires of the magnet are connected to two screws in the side of the case and to which the telephone cord is con-

nected. The screws are insulated with little rings of hard rubber slipped over them and these keep them from touching the metal case. If the screws were not *insulated* in this way the elec-

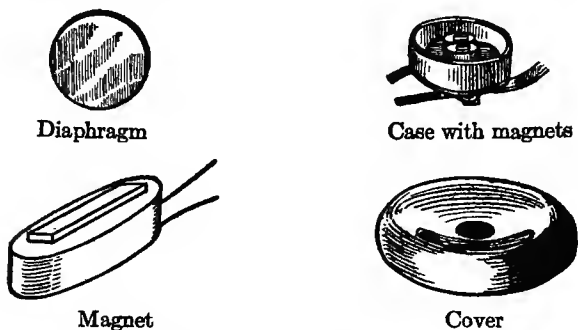


FIG. 23.—TELEPHONE RECEIVER TAKEN APART.

tricity from the dry cell would flow from one screw to the other across the case instead of flowing through the coil of fine wire around the magnet.

The edge of the disk of sheet iron just fits the outside edge of the case but does not touch the top of the magnet, a space

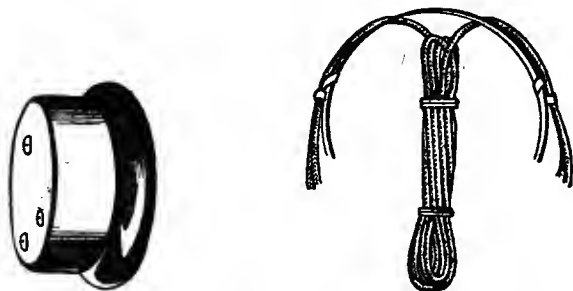


FIG. 24.—RECEIVER COMPLETE.

FIG. 25.—TELEPHONE CORD.

being left between them of about $\frac{1}{8}$ inch. The cover when screwed on the case holds the iron disk firmly by its edge, but does not touch it anywhere else, and this allows it to *vibrate* freely.

The receiver shown in Fig. 24 is called a *watch-case receiver*, because it is about the size of a watch. A watch-case receiver nickel-plated and with a hard rubber screw cap weighs about 6 ounces and can be bought for 75 cents or \$1.00. An ordinary telephone cord 3 feet long can be bought for about a quarter. It is shown in Fig. 25.

Connecting Up the Parts.—When you have all of the parts of the receiving set at hand, get a nice smooth board, about 1

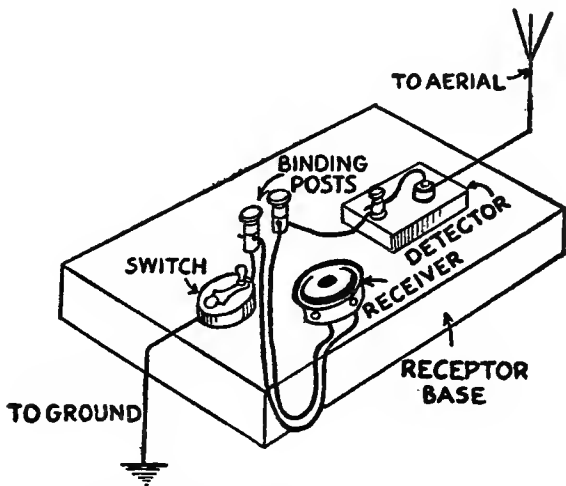


FIG. 26.—THE RECEIVING SET CONNECTED UP.

inch thick, 5 inches wide, and 8 inches long, for the base. Then mount the switch on the left hand side of it, the crystal detector on the right hand side, and screw two binding posts in between them and well toward the back. This will leave plenty of room on the base between them so that the telephone receiver can be laid on it in case you should want to move it. The proper places for the various parts are clearly shown in the outline drawing in Fig. 26.

First connect the wire leading to the aerial with the brass cup of the detector that holds the crystal; then connect the binding post of the detector that holds the wire with one of the large binding posts screwed into the base of the receiving set and insert in it one of the terminals of the telephone receiver; connect the other terminal of the latter with the other large binding post and from this post lead a wire to one of the contact points of the switch. Finally connect the other contact point of the switch with a wire that leads to the water pipe, gas pipe or other ground.

Adjusting the Receiver.—The only adjustment of the receiving set that you need to make is to move the free pointed end of the wire of the detector about on the crystal, while you are listening in, of course, until you find a sensitive spot and then you can adjust the pressure of the wire on it until the sounds are the loudest. This receptor will receive waves sent out by a spark gap sender only as it is not tuned for receiving words or music. Also for this reason it will respond to a wide range of wave lengths and is not, therefore, very *selective*, as it is called. It receives best, however, when the transmitter is sending out wave lengths that it normally receives.

When the switch is closed and the telephone receiver is held to the ear a slight sound, something like bacon frying in a skillet, can be heard. If, now, the detector is connected to an *aerial wire* and a *ground* and some operator from a station that is not too far away is sending, you will be able to plainly hear the dots and dashes as he clicks them off with his key, and if you can read the *International Morse Code* you will have the pleasure of picking the messages right out of the air as they shoot by at the speed of light.

While this is the simplest receiver that can be made it is far from being the best, as it cannot be tuned and is very wasteful of the received energy. You can make a much better receiving set by including a tuning coil and a condenser. This arrangement will not only permit you to tune in any amateur or broadcasting station but the signals will come in much clearer and stronger as the energy of the received waves is conserved.

COST OF RECEIVER WHEN PARTS ARE BOUGHT

Switch.....	\$.30
Telephone receiver.....	.75 to 1.00
Telephone cord.....	.25
Detector ¹	1.70
Two binding posts.....	.20
	<hr/>
Total.....	\$3.20

COST OF RECEIVER WHEN PARTS ARE MADE

Switch.....	\$.10
Telephone receiver.....	.75 to 1.00
Telephone cord.....	.25
Detector.....	.35
Two binding posts.....	.20
	<hr/>
Total.....	\$1.90

¹ Can be bought of the J. H. Bunnell Co., Park Place, New York City.

CHAPTER III

A CHEAP AËRIAL WIRE

Although the *aërial wire* is merely two or three wires strung between two high places it is an important part of wireless and it must be put up right.

There are three things which go to make a good aërial and these are:

- (1) To have the wires as *high* as possible,
- (2) To have as long a *stretch* of wire as possible, and
- (3) To have the wires well *insulated* at the ends.

The first thing to do is to choose two places as high and as far apart as you can find and one of which is near your operat-

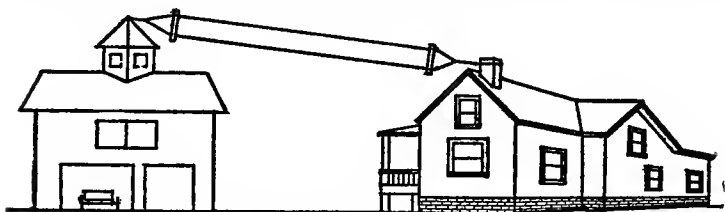


FIG. 27.—AËRIAL SUSPENDED BETWEEN HOUSE AND BARN.

ing room, and still have a clear sweep between them, that is, there should be no trees or anything else in the way to interfere.

One end of the aërial should be put up so that it will come close to the room where your wireless set is located. Suppose, for example, that your house and the barn are 100 feet apart. Then the aërial wires can run between the gable ends of the house and the barn as shown in Fig. 27. If there is no barn on your place, attach the end of the aërial to a chicken-coop or

even to a near-by fence. Whatever you do though, get the aërial as high above the ground as you can.

There are five parts to an aërial and these are:

- (1) The *wire*, of which the aërial is made,
- (2) The *spreaders*, for keeping the wires apart,
- (3) The *insulators*, for keeping the wires from touching the spreaders,
- (4) The *rope*, for suspending the aërial, and
- (5) The *leading-in* wire, which connects the aërial wires with the sending and receiving apparatus.

Kinds of Wire.—Any kind of wire will do for an aërial, but aluminum or copper wire about $\frac{1}{8}$ inch in diameter makes a very good one, that is if the aërial is a short one. Iron wire is much cheaper than copper wire, but it is not nearly as good for wireless work. If you want to use iron wire, try to get regular telegraph wire; this iron wire is *galvanized*, which means that it is plated with zinc. Galvanized iron wire is better for aërials than ordinary iron wire as it does not rust and conducts electricity better.

If neither copper wire nor galvanized iron wire can be had, use any kind of wire you can get and never mind the size as long as it is strong enough to hold together when strung up. Get as



FIG. 28.—SPREADER WITH HOLES.

many feet of wire as you need for the distance between the places where you intend to suspend the aërial. When you have the wire, cut it in half and lay the two pieces side by side on the ground.

The Spreaders.—These are merely sticks of wood to keep the wires apart when they are in the air and to prevent them from getting twisted. For an aërial 100 feet long a stick, or spreader, at each end will be enough. For longer spans than 100 feet a spreader should be placed in the middle of the aërial.

For the spreaders get two sticks about 4 feet long, 1 inch

thick and 3 inches wide, and bore a hole $\frac{3}{4}$ inch in diameter and 3 inches from each end; also bore two more holes of the same size at each end but 6 inches nearer the middle of the stick than the outside holes. Fig. 28 shows the spreader and the places where the holes are to be bored.

The Insulators.—Just as ordinary telegraph wires are looped around glass insulators to keep them from touching the



FIG. 29.—PORCELAIN INSULATOR.

telegraph poles, so the ends of the aërial wires are passed through *porcelain insulators* to keep them from touching the spreaders. These insulators are tubes made of porcelain and are about $\frac{3}{4}$ inch in diameter and 4 inches long. One end of the insulator is bulged out so that it cannot slip through the holes in the spreader. Fig. 29 is a picture of one of these insulators.

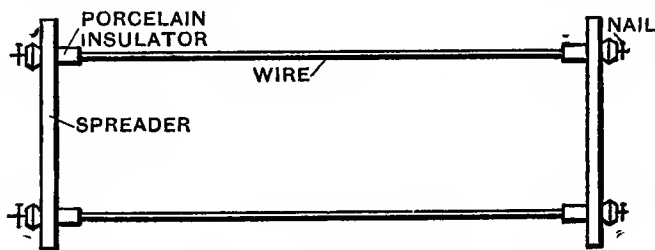


FIG. 30.—SPREADERS WITH INSULATORS AND WIRES.

Four porcelain insulators will be needed for the aërial—two at each end. Push an insulator in the outside hole of each spreader. Now lay a spreader at each end of the wires on the ground with the heads, or bulged part of the insulators away from each other as shown in Fig. 30. Then slip the ends of the wires through the insulators and twist the end of each wire

around a nail so that the wires cannot slip out after the aerial is hoisted into the air and drawn up tight.

The Rope.—The next step is to fasten a rope to each spreader. Each piece of rope should be about 15 feet long, more or less as may be needed; put an end of one piece of the rope through the holes in a spreader, loop it back and *splice*, or tie it to the other part of the rope so that it cannot work loose. Fasten

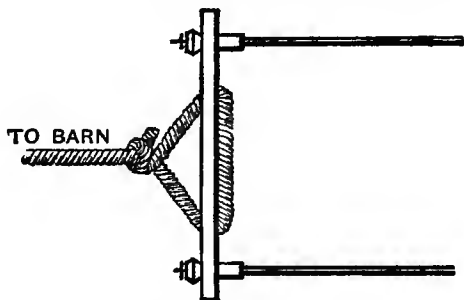


FIG. 31.—ROPE THROUGH SPREADER.

a piece of rope to the other spreader in the same way. Fig. 31 shows how it is done.

The Leading-in Wire.—The wires which connect the apparatus with the aerial are formed of:

- (1) The *bridle*, or loop of wire whose ends connect with the wires of the aerial, and
- (2) The *leading-in wire*, or wire connecting with the bridle and which is brought in the room through the window and connects with the *aërial switch*.

The Bridle.—To make the bridle, take about 8 feet of wire and twist one end to one of the aerial wires and twist the other end around the other aerial wire. These wires should be soldered to the aerial wires in order to make good connections. This is the part of the aerial wire which is called the *bridle*.

The Leading-in Wire.—To the middle of the loop, or *bridle*, so formed, twist and solder another piece of wire and be sure

this is long enough to reach down and through the window and to your apparatus. This piece of wire is called the *leading-in wire*. It is shown in Fig. 32.

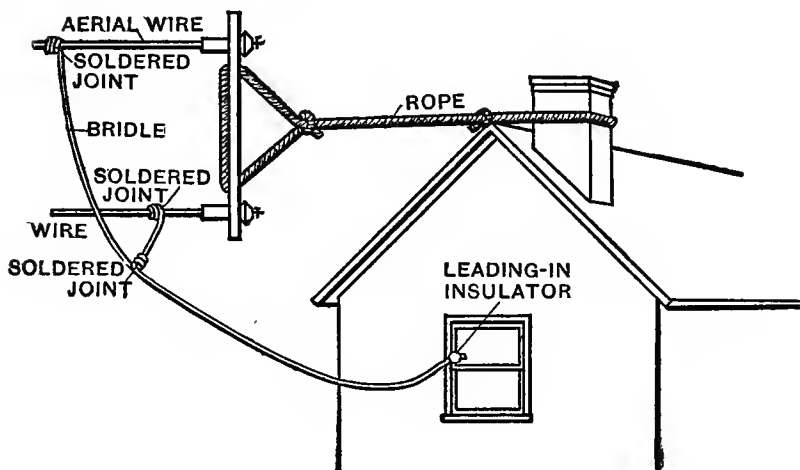


FIG. 32.—AËRIAL COMPLETED AND PUT UP.

The Leading-in Insulator.—The aerial wire must not touch trees, buildings or other objects, but of course it must be supported in the air by something, so porcelain insulators are put in the spreaders to keep the wires from touching the wood. This is done to keep the electricity on the wires from running away and soaking into the wood.

Now this same thing will happen when the leading-in wire is brought from the outside of the house into the operating room unless it is well insulated. An easy way to insulate the leading-in wire is to bore a hole $\frac{3}{4}$ inch in diameter through the window sash and push a porcelain insulator as shown in Fig. 29 through it. The end of the leading-in wire of the aerial is pulled through the insulator in the window sash and brought down to the aerial switch in the operating room to which it is connected.

The Aërial Switch.—The purpose of the aërial switch is to connect the aërial wire first to the sender and then to the receiver, or the other way about, depending on whether you want to send or receive a message.

One thing is certain, the sender and the receiver must not be

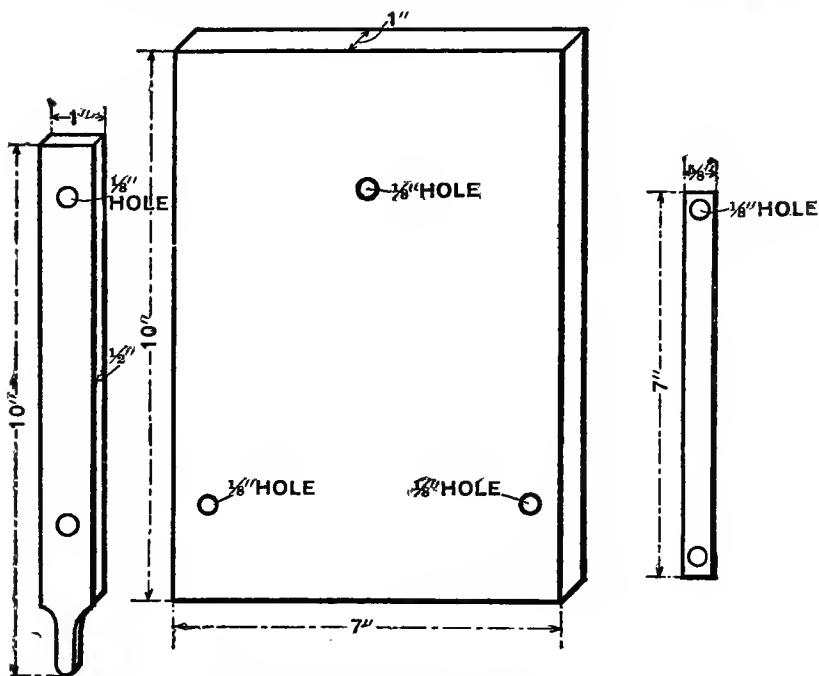


FIG. 34.—
LEVER OF
AËRIAL
SWITCH.

FIG. 33.—BASE OF AËRIAL SWITCH.

FIG. 35.—
STRIP OF
BRASS OF
LEVER.

connected to the aërial wire at the same time for the reason that the spark from the spark-coil would *burn out* the detector when messages are being sent; nor should they be connected when receiving a message, for much of the current set up in the aërial wire by the incoming waves will flow through the sender and so weaken the message.

To make an aërial switch, get a board about 10 inches long, 7 inches wide and 1 inch thick. Drill three $\frac{1}{8}$ -inch holes at the places marked with circles as shown in Fig. 33. Make a lever of a piece of wood 1 inch wide, $\frac{1}{2}$ inch thick and 10 inches long; drill a $\frac{1}{8}$ -inch hole at the place marked with a circle, and round off the other end with a knife to make a handle as in Fig. 34.

Cut a strip of sheet brass 7 inches long, $\frac{1}{2}$ inch wide and $\frac{1}{32}$

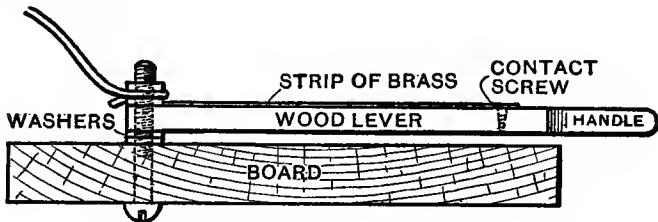


FIG. 36.—CROSS SECTION OF AËRIAL SWITCH.

inch thick and drill a hole in each end so that when the strip of brass is laid over the wooden lever the holes will come exactly together. This piece of brass is shown in Fig. 35.

The next thing to do is to put a wood screw through a hole in the strip of brass and screw it in the wood lever nearest the handle so that the head of the screw sets in *flush*, that is, even

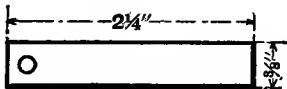


FIG. 37.—BRASS STRIP FOR CONTACT SPRING.



FIG. 38.—CONTACT SPRING.

with the surface of the strip of brass. The lever is attached to the board by putting a machine screw $1\frac{3}{4}$ inches long through the upper hole in the board (see Fig. 35) and the upper holes of the wood lever and the brass strip; before putting on the lever a couple of brass washers should be slipped on the screw so that the under part of the lever will be raised away from the board a little and can be moved freely from side to side.

A cross-sectional view, as if the switch was split right down the middle, is given in Fig. 36 and shows how the washers and screws should be placed through the lever and the board. One thing more, cut out two pieces of spring brass $2\frac{1}{4}$ inches long and $\frac{3}{8}$ inch wide, and drill a $\frac{1}{8}$ -inch hole in one end as marked by the circle in Fig. 37; then bend the strips into the shape shown in Fig. 38 and screw one to the left-hand side of the board and the

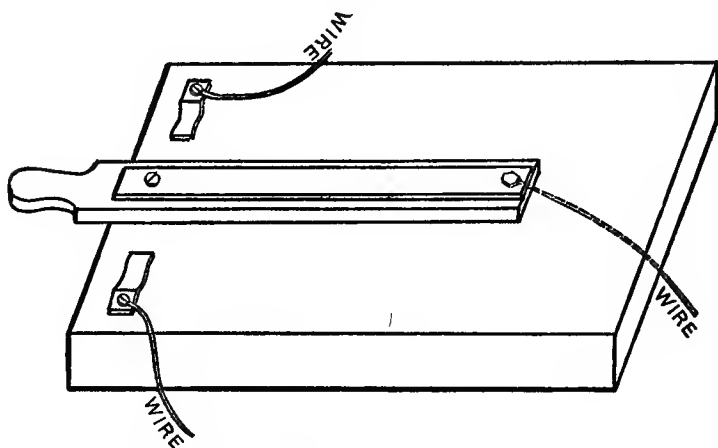


FIG. 39.—AÉRIAL SWITCH COMPLETE.

other to the right-hand side of the board. Put the screws in from the back of the board and screw two nuts on each screw on top of the brass contact springs.

A wire is connected to each of these contact springs and another wire is connected to the top screw of the lever. These connections are easily made as the wire is bent round the screw between the nuts and the latter are then screwed down tight. Fig. 39 shows the aerial switch complete.

The Ground Connection.—There is one thing you must look after to put your station in working order and that is the *ground*. To *ground* an apparatus means to connect it with a sheet of metal that is buried in the ground, or some metal.

object such as a gas- or a water-pipe which leads to and runs into the ground.

A fairly good ground can be made by soldering a heavy wire to a sheet of zinc 3 feet by 4 feet and burying the zinc in the ground deeply enough so that it will always be moist. The ground wire need not be insulated from the building but it can be brought into the house and led to the operating room in any way that is easiest.

Connecting up the Sender and Receiver to the Aërial and Ground.—Connect the top wire of the aërial switch to the leading-in wire of the aërial. To the left-hand lower wire of the aërial switch connect the wire of the binding post of the detector marked *to aërial* as shown in Fig. 40, which is a complete wiring diagram of the whole station. Connect the right-hand lower wire of the aërial switch to the binding post of the spark-gap marked *to aërial switch*. Connect the wire of the binding post of the detector marked *ground* with the sheet of zinc buried in the ground; and finally connect the binding post of the spark-gap marked *to ground* to the same wire that the detector is connected with and which leads to the zinc plate in the ground. In other words, one sheet of zinc furnishes a ground for both the sender and the receiver. All of the connections are clearly shown in the outline drawing Fig. 40.

A *single pole, single throw* switch must be connected in between the top wire of the aërial switch and ground wire as shown in Fig. 40. This switch is to protect your apparatus from what is called *static electricity*, that is electricity which charges the air and the ground just before the coming of a storm. When sending and receiving this switch is *open*, but always *close* it when you are through working. A switch of this kind can be bought, or if you want to make one you will find the drawings, Figs. 147 and 148, and description needed on page 151. Before using your set read the Fire Underwriters' Rules given in Chapter III, Part III, page 199.

To send a message throw the lever of the aërial switch to the *right* and work the Morse key. To receive a message throw the

aërial switch to the left; close the receiver switch and hold the telephone receiver to your ear.

When you have finished throw the lever of the aërial switch to the *right* as for sending, and always leave it in that position except when you are *listening-in*, as this prevents *static electricity* from charging the aërial wire. When you have completed your set you can connect your receiver with the aërial and *listen-in*, but you must not connect your sender to the aërial and send until you have obtained a license from the Government as explained in Chapter III, Part III.

COST OF MATERIALS TO MAKE A 100-FOOT AËRIAL¹

250 feet of No. 14 Brown & Sharpe gauge copper wire	\$1.50
Or 250 feet of galvanized telegraph wire.....	.60
2 4-foot spreaders .....	.20
5 porcelain insulators (4 for aërial and 1 for leading in) .....	.50
30 feet of $\frac{3}{4}$ -inch manilla rope.....	.60
<hr/>	
Total cost for aërial with copper wire.....	\$2.80
Total cost for aërial with telegraph wire.....	1.90

AËRIAL SWITCH

Board	\$.20
Screws, washers and nuts.....	.15
Strips of brass.....	.10
<hr/>	
Total .....	.45

GROUND

1 sheet of zinc 3 x 4 feet.....	.50
---------------------------------	-----

Total cost of aërial, aërial switch and ground\$3.30 or \$4.20

¹ These are only approximate prices. Very often enough wire, rope, wood and zinc can be found in the cellar, attic or woodshed to make the aërial, switch and ground.

CHAPTER IV

LEARNING THE MORSE CODE

In the early days of North American history certain tribes of Indians had a crude way of sending signals without wires. When the Indians went on the warpath and they wanted to signal to others of their tribe some distance away that they were ready to scalp the pale-faces, which was usually at night, one of the braves would place a burning arrow in his bow and shoot the flaming signal high into the air. The distant watchers who were in on the secret would know at once what was meant when they saw its light. It was a way to signal without wires but it was not wireless telegraphy as it is done to-day. We have to remember though that the Indians were savages while we are highly civilized, or think we are.

The point I want to bring out, though, is that a burning arrow, the letters of the alphabet or the clicking of a telegraph instrument may mean whatever we have agreed beforehand that they shall mean. In other words they are merely *codes*, that is signs and signals which convey our ideas to others.

The Code.—In real wireless telegraphy, a *code* of dots and dashes is used by operators to send and receive messages. The word *code* in telegraphy means a set of electric impulses or signals, arranged in advance and which can be sent from one station to another station by the use of proper apparatus.

This *code* is formed of a number of *dots* and *dashes*, and each letter of the alphabet is represented by a dot, a dash, or by dots and dashes together. For example, suppose you are at one end of the table and I am at the other end and we each have a pencil. Now suppose I tap three times on the table with my pencil like this ● ● ● and that we have agreed before-

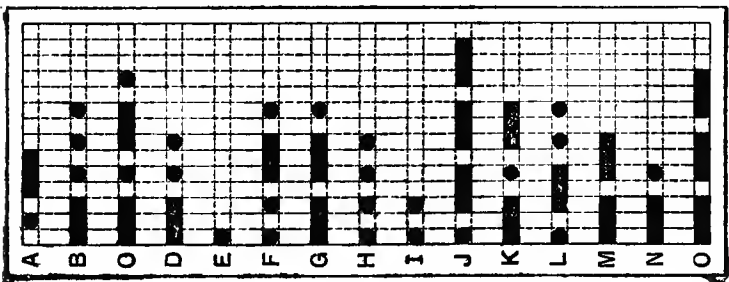
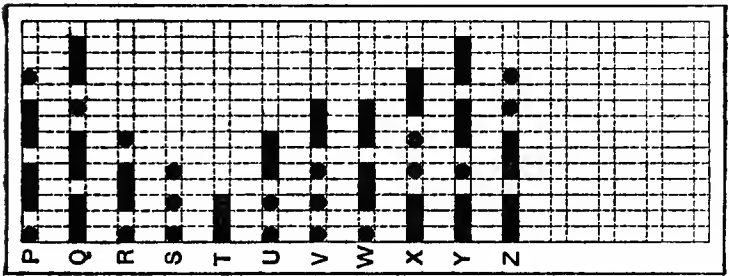
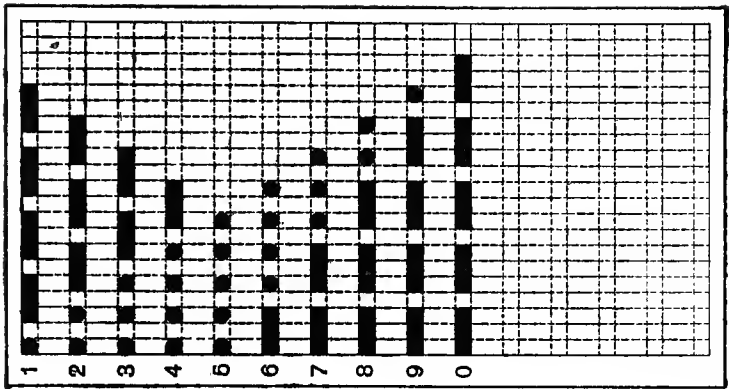


FIG. 41.—INTERNATIONAL MORSE CODE.

hand that when I make three taps, or dots, on the table you are to understand it to mean the letter S; suppose we have also agreed that when I tapped the end of the pencil on the table three times but held it down a second or so between the taps like this [] [] [] it will mean the letter O.

Now if I tapped out on the table three dots, ● ● ●, three dashes, [] [] [], and again three dots, ● ● ● you would read it as S O S, and this is the signal a ship sends out at sea when she is in distress.

Just so with all the other letters of the alphabet; thus A is a dot and a dash like this ● []; B is a dash and three dots, [] ● ● ●; C is a dash, dot, dash, dot, [] ● [] ● and so on.

The dot and dash code, originated by Samuel F. B. Morse, the inventor of the telegraph in 1844, is still used by operators of *land lines* in this country and this code is called the *American Morse code*. In this code there is one letter that has a longer dash than any of the others and there are several letters which have longer spaces, or *time intervals*, between the dots than others; and these things make the code a little harder than it would be if the spaces were all the same.

The International Morse Code.—In Europe someone, somewhere, sometime, thought he would make the code invented by Morse a little more simple and so he got up the code shown in Fig. 41. This code is now in use all over Europe and for this reason it is called the *Continental Morse code*.

Since the wireless telegraph was invented in Europe, when it came to be put on ships that sailed across the ocean, it was natural that the *Continental code* should be used; when the wireless telegraph finally reached America and it was installed on ships in the coastwise trade it was also natural that the *American Morse code* should be used.

When the wireless telegraph came into common use and there were hundreds of shore stations on both sides of the ocean, and every ship had a set, it became necessary for all operators to use

the same code, so that ships in distress could communicate with any other ship or shore station.

For this reason all the countries sent representatives to the *International Radiotelegraphic Convention*, which met in London in 1912 (see Chapter III, Book III, page 196), and they all agreed that their countries would use the Continental Morse code for wireless telegraphy and so it is now known as the *International Morse code*.

How to Learn the Code.—It is much easier to learn to receive the Morse code for wireless work than for ordinary telegraphy since in wireless the dots and dashes are heard as buzzing sounds of different lengths in the telephone receiver, whereas, with the wire telegraph the difference between a dot and a dash is known by the length of the spaces between the clicks made by the *sounder*.

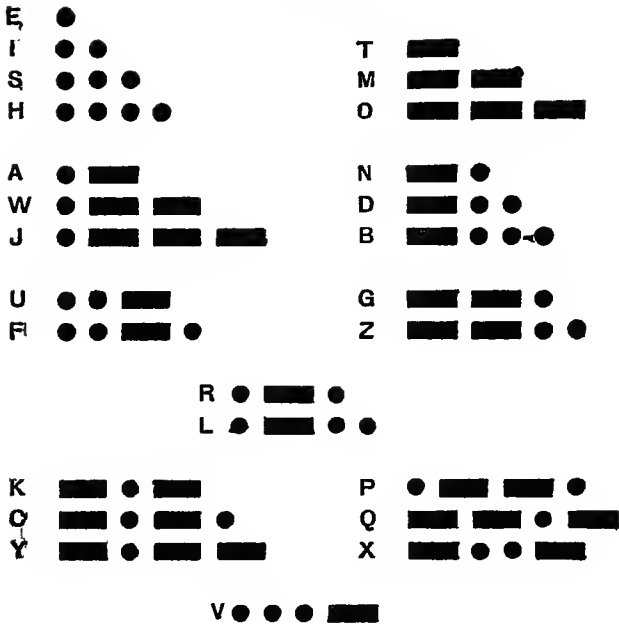
The first thing to do is to study the Morse code until you have learned the dots and dashes of all the letters by heart. If you have a good memory this will be an easy matter, but if you haven't a good memory you still have the satisfaction of knowing that once you have learned the code you will never forget it. The arrangement shown in Fig. 42 may help you to remember the code letters:

The idea is to make all of the dots and all of the dashes follow in a natural order. The figures of the Morse code are arranged exactly on this basis and you will be able to remember these with the slightest effort.

A good way to practice sending and receiving, if there is no other station near you, is to stretch a wire across your room and connect one of the balls of your spark-coil to it and connect the other ball to a wire fastened to a piece of zinc or copper about a foot square and which is laid on the floor. This makes a little sending station in your own room and you will not need a license to operate it.

By holding the telephone receiver to your ear with your left hand and working the sending key with your right hand you can send messages and hear them at the same time. This will give

LETTERS



NUMBERS



FIG. 42.—FIRST AID TO REMEMBERING THE CODE.

you the practice you need until you have mastered the code. When you can send five words per minute, each word to have at least five letters in it, without a mistake, you are well on your way to secure a license and become a real operator.

From five words per minute work up to ten or twelve words per minute; when you have reached this point wireless will be

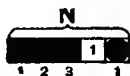


FIG. 43.—LENGTH OF DASH

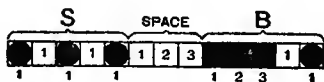


FIG. 44.—SPACE BETWEEN TWO LETTERS.

easy sailing for you and it will not be long before you can receive as fast as the best operators can send.

In learning to send remember that (1) a *dash* is equal to three dots; (2) the *space* between parts of the same letter is equal to one dot, as shown in Fig. 43; (3) the *space* between two letters is equal to three dots as shown in Fig. 44, and (4) the *space* between two words is equal to five dots as shown in Fig. 45.

In sending be careful to make your dots and dashes sharp

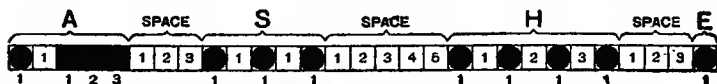


FIG. 45.—SPACE BETWEEN TWO WORDS.

and clear, which means that all the dots are of exactly the same length; all of the dashes the same length, that is, three times the length of the dots, and that the space intervals between them are equal.

Signals of Transmission.—The following signals are taken from the rules and regulations adopted by the International Radiotelegraph Convention of 1912.

(1) Ships in distress shall use the following signal:



The operator is to repeat this signal at brief intervals and then follow with the necessary particulars.

Whenever you hear a ship calling S O S you must stop sending and do not commence again until you are sure that the messages between the ship that called and the ones which answered have ended.

(2) When you want to call a station send this signal first:



Then send the call letter of the station you want and repeat this three times; next send the abbreviation for the word "from," which is



(3) When you and the station you have called are through sending messages send this signal:



and end by sending your own call letters.

Abbreviations in Code.—The following abbreviations are used and understood by all operators and for this reason they are called *conventional signals*. After you have learned the Morse code well you should practice on these:

For instance, suppose you want to send the word "understand"; now instead of spelling this word out in full you simply send



and the operator who is receiving your message will know what you mean.

Period_____	• • • • •
Semicolon_____	████ • █████ • █████ •
Comma_____	• █████ • █████ • █████
Colon_____	████ █████ █████ • •
Interrogation_____	• • █████ █████ • •
Exclamation point_____	████ █████ • • █████ █████
Apostrophe_____	• █████ █████ █████ █████ •
Hyphen_____	████ • • • • █████
Bar indicating fraction_____	████ • • █████ •
Parenthesis_____	████ • █████ █████ • █████
Inverted Commas_____	• █████ • • █████ •
Underline_____	• • █████ █████ • █████
Double Dash_____	████ • • • █████
Distress Call_____	• • • █████ █████ █████ • • •
Attention call to precede every transmission_____	████ • █████ • █████
General inquiry call_____	████ • █████ • █████ █████ • █████
From (de)_____	████ • • •
Invitation to transmit (go ahead)_____	████ • █████
Warning -- high power_____	████ █████ • • █████ █████
Question (please repeat after . . .)--interrupting long messages_____	• • █████ █████ • •
Wait_____	• █████ • • •
Break (Bk.) (double dash)_____	████ • • • █████
Understand_____	• • • █████ •
Error_____	• • • • • • •
Received (O. K.)_____	• █████ •
Position report to precede all position messages)_____	████ • █████ •
End of each message (cross)_____	• █████ • █████ •
Transmission finished (end of work) (conclusion of correspondence)_____	• • • █████ • █████

FIG. 46.—ABBREVIATIONS IN CODE.

CHAPTER V

HOW WIRELESS WORKS

“How do you send wireless messages; and how do you receive them?”

These are the questions most often asked the boy who owns a wireless station, and he should be able to explain how these things are done as well as to understand them himself.

In sending and receiving wireless messages there are some things the eye can see and the ear can hear. For instance, when a message is being sent the eye can see the lever of the key move up and down under the fingers of the *operator*; and when the lever of the key is pressed down the eye can see a stream of sparks, or lightning on a small scale, jump between the brass balls of the spark-gap, and the ear can hear a lot of crisp, crackling sounds which is really thunder, caused by the miniature lightning.

When a message is received there is nothing for the eye to see and but little for the ear to hear, but that little may mean a great deal especially if it is an S O S signal from some ship in distress. The sounds heard are just faint buzzings of the diaphragm of the telephone receiver like a fly in an uncorked bottle.

But there are other things that take place, other forces that are at work, both at the sending end and the receiving end, and in the space between, which neither the eye can see nor the ear can hear, and to understand what is going on we must know a little about electricity and its twin brother *magnetism*.

What Takes Place When the Key Is Closed.—Now although neither electricity nor magnetism can themselves be seen, we can get a pretty clear idea of how they work by comparing them with things which we can see. Thus electricity behaves

very much like water. We can think of a battery as being a pump, in fact it is an electricity pump; the coils of wire of the spark-coil and the wires that connect the key and the battery may be likened to a pipe in which the water flows, while the key is a valve for turning on and off the electricity.

Let the *outlet* of a rotary pump, such as is used on an automobile engine, be connected with a coil of pipe at one end and the other side of the valve with the intake of the pump as shown in Fig. 47.

Now when the pump is turned by a crank and the valve is set so that the water can get through it there will be a constant flow of water through the coil of pipe; but if the valve is turned so

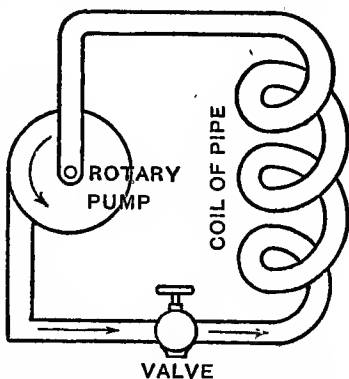


FIG. 47.—A CURRENT OF WATER FLOWING IN A COIL OF PIPE.

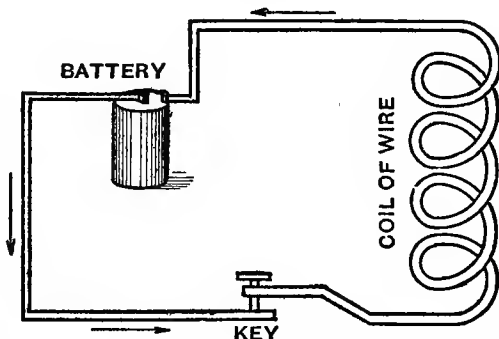


FIG. 48.—A CURRENT OF ELECTRICITY FLOWING IN A COIL OF WIRES.

that it is closed, of course no water can flow through the pipe or circuit.

The same thing happens when the lever of a telegraph key is

pressed down for this closes the circuit, that is when the wire, or path, which includes the primary coil of the spark-coil is *made* by the key the electric current is forced through it by the battery. When the lever of the key is *up*, the circuit is broken and the current can no longer flow through the wire of the spark-coil. This arrangement is shown in Fig. 48.

The interruptor of the spark-coil is used to make and break

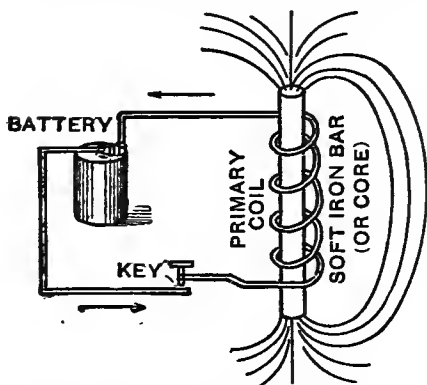


FIG. 49.—A BAR OF IRON, MAGNETIZED BY CURRENT OF COIL.

the battery current a large number of times, while the key is *closed* so that the aerial wire and ground wire can be rapidly *charged* and *discharged* through the spark-gap to make the sparks follow each other quickly. The purpose of the interruptor of the spark coil is to make and break the primary current very rapidly and this

changes the direction of the current in the secondary coil several hundred times a minute.

If an insulated wire, called a primary coil, is wound round a bar of iron as shown in Fig. 49, and a current is sent through the coil of wire by a battery, the iron bar will be *magnetized*, that is the ends of the bar will attract needles, the blades of pocket-knives and other steel things to it. Such a bar of iron is called a *core*.

Again if a large number of turns of fine insulated wire is wound around a primary coil which has a core in it as shown in Fig. 50, and a current is sent through the primary coil, the iron bar will be magnetized as before and the magnetism will set up another, or a secondary electric current in the fine wire which forms the secondary coil.

In this way electric currents can produce magnetism and in turn magnetism can produce electric currents. Further, magnetism can pass right through glass or the cotton covering of insulated wires and for this reason the electricity in the primary coil can be changed over, or transferred to the secondary coil though they are insulated from each other. Each time the primary circuit is closed by the key a current will flow through

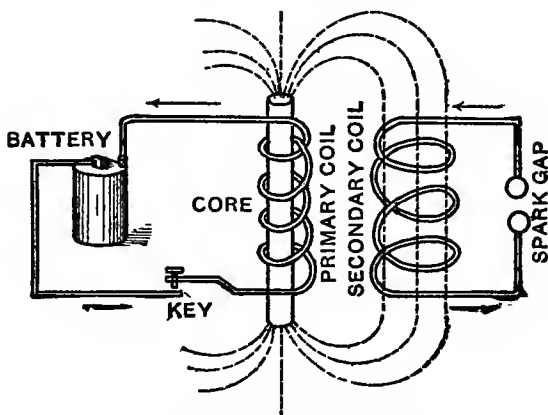


FIG. 50.—CURRENTS ARE SET UP IN THE SECONDARY BY MAGNETIC LINES.

the secondary coil in one direction and each time the primary circuit is broken by releasing the key another current will flow through the secondary coil in the opposite direction.

But the fine wire, or secondary coil, does more than to merely produce these *alternating currents*, as currents which flow first in one direction and then in the other are called, for it also raises the *pressure* of the currents.

To illustrate what it meant by saying that the *pressure* of the electric current is raised, let's see how water from a hydrant acts when it is forced through a nozzle. The *pressure* of the water from the hydrant though the hose may not be very great and without a nozzle a large amount of water would spout out a few feet only; but screw on a nozzle, that is a tube having a

very small hole in the end, and though a smaller amount of water will squirt out of it, it will squirt much farther for *the pressure* of the water has been raised.

What the Spark Does.—The same thing takes place in a spark-coil. The amount of electricity in the fine wire of the secondary coil is very much less than that in the primary coil, but the secondary coil *raises the pressure* of the current so that by the time it reaches the spark-gap balls it jumps right through the air between them.

When the electricity jumps across the gap it burns up the air between the spark-gap balls and the burning air makes a flash which we call the spark. As fast as the air is burned up in the spark-gap the air around it rushes in to fill up the empty space and this inrushing air makes the crackling sound; the same thing happens when an electric light bulb is dropped on the floor; the bulb has had the air pumped out of it and when broken the air around it rushes in and makes a crack like a pistol shot.

What High-Frequency Currents Are.—Now that we have an idea as to how the spark-coil changes the low-pressure current of the battery into high-pressure currents which make the jump sparks, we will follow this up and find out what the spark has to do with the aërial and ground wires.

In some ways an electric current also acts very much like a rubber ball and this is the case with electricity in an aërial and ground wire. If you throw a rubber ball on a sidewalk it will bounce quite high the first time, not so high the next time and a little lower each time, until it no longer bounces at all, but lays at rest on the walk. If we make a line on paper to show how the ball bounced it would look about like that shown in Fig. 51.

When you raise a ball ready to throw it on the sidewalk *force* is stored up in it and all that is needed is to let it go. Just so with the electricity in or on the aërial and ground wires before the spark takes place.

There is power back of the ball and power back of the electricity in the aërial and ground wires; making the spark is just

like throwing the ball, they both release their stored-up energy; the ball on striking the sidewalk bounces up into the air, while the electricity on reaching the end of the ground wire bounces up to the top of the aerial wire, and just as the ball bounces into the air every time it strikes the sidewalk, so the electric current bounces to the top of the aerial wire every time it strikes the ground.

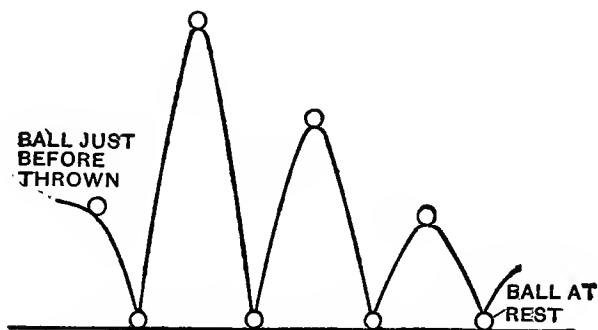


FIG. 51.—HOW A RUBBER BALL BOUNCES.

You may wonder how the electric current in the aerial can pass between the spark-balls on its way to the ground and back again, since air is an insulator. It is because the spark has burned the air out of the gap and this hot space makes as good a path for the electricity as though the brass balls were connected at that instant with a copper wire.

Just as a ball can be started bouncing again after it is at rest by throwing it on the sidewalk so a current in the aerial and ground wires can be started by pressing down the key and making a spark.

Thus, we find that every time a spark jumps between the balls a current of electricity surges up and down the aerial and ground wires and if we could trace its motion on paper as we have the rubber ball we would have a wiggly line like that shown in Fig. 52.

While it has taken a long time to explain about the current

in the aerial and ground wires, it travels up and down faster than the mind can think, that is to say a million times every second, more or less.

How Wireless Waves Are Made.—The purpose of the current surging up and down the aerial wire of the sending station is to send out waves to the receiving station. An easy way to

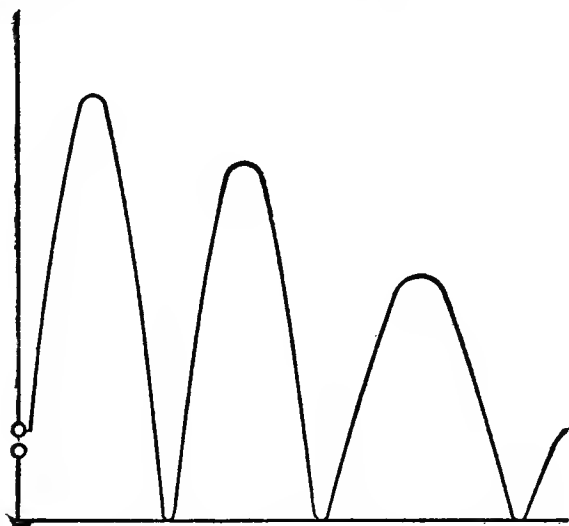


FIG. 52.—ELECTRIC CURRENT IN AN AÉRIAL WIRE.

understand how this is done is to pick up a dozen stones and stand on the bank of a pool of still water.

Throw a stone into the center of the pool and you will see a ripple or small wave form in a ring around the place where the stone struck the water, and you will also see that the ring spreads out in every direction and as it grows larger it also grows weaker until it can no longer be seen.

After this experiment throw one stone in the pool after another quickly and a number of waves always traveling toward the edge of the pond will be set up and follow each other.

This is a fair picture of what happens when the electric cur-

rents run up and down the aërial and ground wires every time a spark jumps between the balls of the gap.

The running currents set up waves in space which travel away from the aërial in every direction, growing larger and weaker until they can no longer be detected.

How Wireless Waves Travel.—All around the aërial wire, everywhere as far as the eye can reach and beyond the space is filled with a substance of which electricity is made and which is perfectly still, just as the pool of water is still before the stones are thrown in, and, too, just as little waves are sent out by the stones striking the water, so the currents running up and down the aërial and ground wires strike this great pool called the *ether* and sets it into motion, and ripples or waves are sent out all around the aërial wire, somewhat after the manner shown in Fig. 53, but instead of being simple rings of elec-

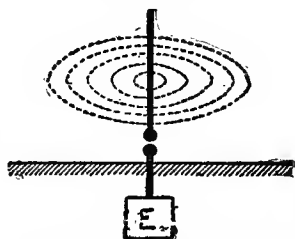


FIG. 53.—ELECTRIC WAVES AROUND AËRIAL.

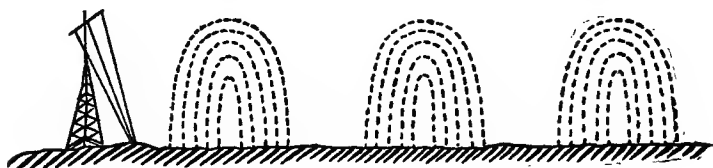


FIG. 54.—ELECTRIC WAVES THROWN OFF BY AËRIAL.

tricity they are shaped more like the half of an orange, as shown in Fig. 54.

How Wireless Waves Are Detected.—As you learned in building the wireless set, the detector of the receiver is connected with an aërial and ground wire when receiving just as the spark-gap is connected with the aërial and the ground when sending. The detector has been called a *wireless eye*, for it

detects or makes known that which our eyes are unable to see, and that is feeble electric currents.

Going back again to the experiment of throwing stones into a pool of water, if you will put a cork on the still water near the edge of the pool, you will see the cork bob up and down every time a stone strikes the water, or rather as soon as the wave set up by the stone reaches the cork. The cork is then a kind of crude detector.

When the electric waves sent out by the aërial wire of a sending station strike the aërial wire of a receiving station, electric currents are set up in the aërial of the receiving station and run up and down the aërial wire through the detector and the ground wire exactly like the electric currents set up in the sending aërial, as shown in Fig. 52.

Where the water waves caused the cork to bob up and down, the electric waves set up electric currents in the aërial wire and these run through the crystal detector, but they can't flow back again; the result of this action is to change them into pulsating currents which can flow through the telephone receiver and this energizes the magnet of it which in turn attracts the diaphragm and the movement of it makes a sound.

Just the instant the electric current stops running up and down the aërial wire and through the detector, the magnet of the telephone receiver is de-energized and there is no further action until another train of electric currents flows through the detector.

How Electric Currents Are Changed into Sound Waves.

—We have seen how a current of electricity flowing through a coil of wire which is wound on a soft iron core makes a magnet of it.

The magnet of a watch-case telephone receiver is very small, as Fig. 55 shows, and is a thin flat piece of steel which is in itself a magnet; this magnet forms the core on which is wound a large number of turns of silk-covered copper wire which is almost as fine as a hair.

When the pulsating current of the detector flows through

the coils of the magnet of the telephone, the steel core is magnetized and any change in the amount of current flowing through the coils will vary the strength of the magnet.

When a high-frequency current is set up in the aerial wire by an incoming wireless wave this current is changed by the

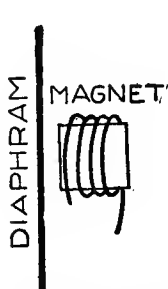


FIG. 55.—MAGNET AND DIAPHRAM OF TELEPHONE RECEIVER.

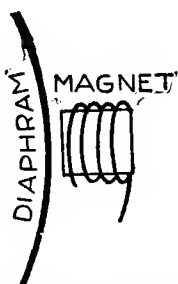


FIG. 56.—A STRONG CURRENT PULLS DIAPHRAM TO MAGNET.

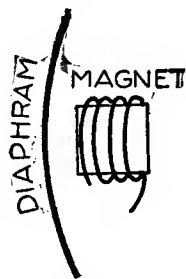


FIG. 57.—WHEN CURRENT STOPS DIAPHRAM SPRINGS BACK.

detector as we have seen, into pulsating current and when this takes place the current from the dry cell can flow through the detector and the coils of the magnet of the telephone receiver.

When the oscillating currents stop flowing in the aerial wire, there are none to be rectified, that is, to be made into pulsating currents, by the crystal detector and so, of course, there is no current to affect the coils of the telephone magnet.

This is the way that high frequency currents running up and down the aerial and ground wires and through the detector are changed into pulsating currents that can energize the coils of the telephone magnet, and this, naturally, changes the strength of the magnet.

The soft iron disk or diaphragm of the telephone (see *Fig. 55*) is set over and very close to the end of the magnet. The edge of the diaphragm is held fast between the case and the cap of the receiver, but the center of the diaphragm which is directly over the magnet is free to move, or vibrate.

Now since every change in the amount of current which flows through the coil of fine wire changes the strength of the magnet which forms the core, the diaphragm, since it is of soft iron, is pulled in toward the end of the magnet, as in Fig. 56, and when released it springs back as in Fig. 57. As the diaphragm moves to and fro very rapidly, or vibrates, under the action of the changing strength of the magnet it gives out a sound like a honey bee on a flower.

How the Message Is Heard.—We have just seen that the diaphragm of a telephone receiver vibrates and that this vibra-

tion is the cause of the buzzing sound we hear.

Now let's see just why a diaphragm when it vibrates sets up what we call a sound, and let's see just how our ears hear the air waves which we call sound.

When the dia-

phragm vibrates it causes the particles of air all around it to dance exactly in step with it and if the telephone receiver is held close to the ear the air which is set into motion cannot get away, but is held like a cushion between the diaphragm and the *drum* of the ear.

The human ear (see Fig. 58) is very much like a telephone receiver in that it also has a thin diaphragm, which we call the *drum*, but instead of being worked by an electromagnet it vibrates whenever the air outside the ear is set into motion; this being the case when the diaphragm of a telephone receiver sets the air into motion the drum of the ear vibrates exactly with it.

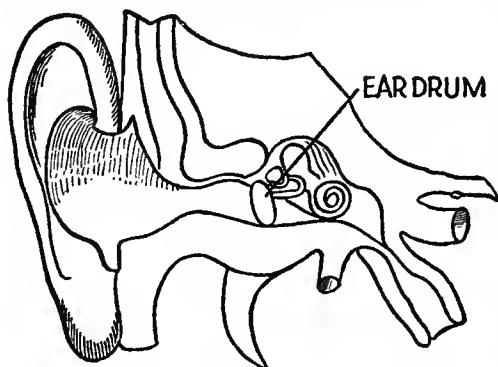


FIG. 58.—THE HUMAN EAR, SHOWING EAR-DRUM AND AUDITORY NERVE.

Connected with the ear-drum is an apparatus which ends in the *auditory* nerve and this nerve in turn leads to the brain. The ear-drum acts as a sender and the auditory nerve as a wire and when the ear-drum vibrates the brain is set a-tingling and this is what we call the sense of hearing.

This then is what happens when you hear the sounds a telephone receiver makes as it buzzes out the dots and dashes. The telephone receiver, then, makes a buzzing sound as long as the needle and the leads of the detector remain cohered, which is only as long as the electric waves last which strike the aerial.

It must be clear now that for whatever length of time the key at the sending station is pressed down the telephone receiver will buzz at the receiving end. This is how wireless works in about as few words as it can be told.

PART II

A LONG DISTANCE WIRELESS SET

CHAPTER I

THE TRANSMITTER

After you have put up and used the small wireless set, the making of a long distance set described in this chapter will not be a very hard thing to do and its operation will be a real pleasure.

The transmitter is made so that waves of a given length can be sent out and the receptor is made so that different lengths of waves can be received. The Government will not permit you to use a wave length that is more than 200 meters long, that is, 656 feet, but with the receptor waves of almost any length can be received and you can *listen-in* to almost any station that is sending.

All of the parts of this set are made of materials that are easily gotten and they are put together in as simple a fashion as possible.

There are two things, though, you should know something about before you try to make and use this larger set. The first is how to read *diagrams* and the second is the first principles of the electric current.

How to Read Diagrams.—In wiring together the different parts which go to make up the sender, but which we will from now on call the *transmitter*, and the receiver which is better called the *receptor*, to keep it from being confused with the telephone receiver, the following *symbols*, which are called *conventional symbols*, will be used. When an arrow is marked across

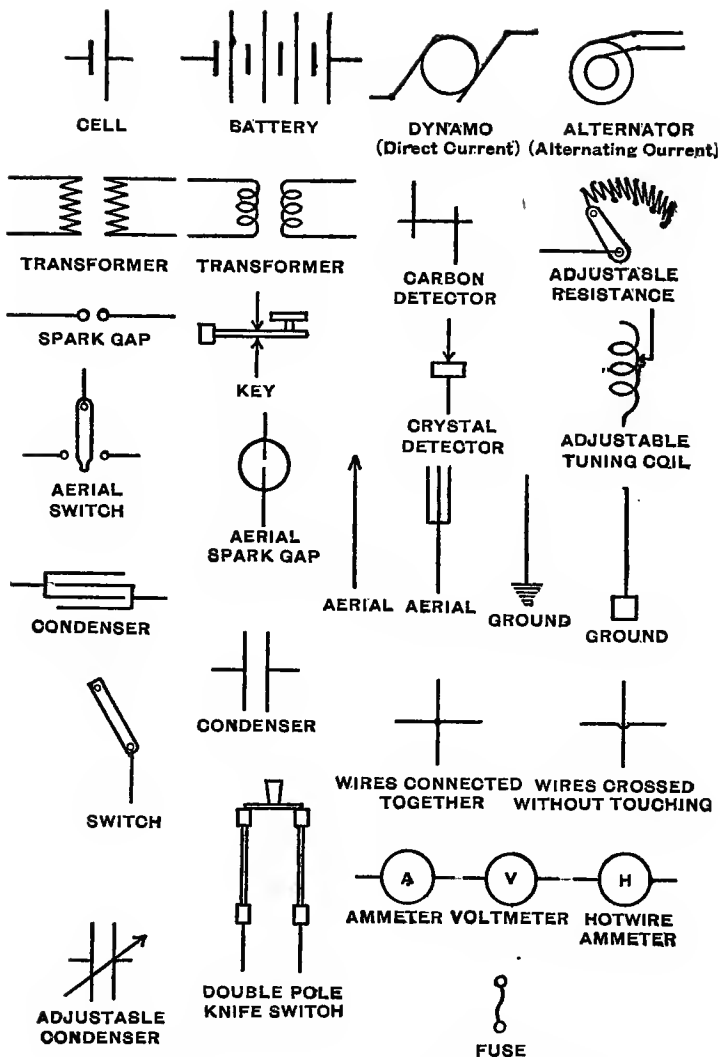


FIG. 59.—SYMBOLS USED IN WIRELESS TELEGRAPHY.

a symbol, it means that the apparatus represented is *adjustable*.

As an illustration, suppose we want to show a *condenser*, a *tuning coil* and a *spark-gap* connected together. It is not necessary to draw a complete picture but merely draw the symbols representing these parts as shown in Fig. 60.

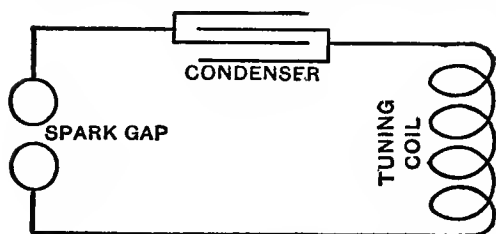


FIG. 60.—DIAGRAM OF CONDENSER, SPARK-GAP AND TUNING COIL.

—In the chapters describing the small wireless set

Things to Know about a Current.

—In the chapters describing the small wireless set

the words *current* and *pressure* were used a great deal. A point has now been reached, though, where something more definite must be known about an electric current if a good station is to be built.

An electric current flowing in a wire, like water flowing in a pipe, has both *quantity* and *pressure*. When we speak of a *current* we usually mean both the quantity of electricity and the *pressure* which moves the *quantity* along the wire. But strictly speaking, *current* means *quantity*.

- (1) A *current* or *quantity* of electricity is measured by a unit called the *ampere* just as water is measured by a unit called the gallon.
- (2) The *pressure* of electricity is measured by the *volt* just as the pressure of steam is measured by the pound.
- (3) The *watt* is the unit of work done, or the unit of work capable of being done by an electric current, just as horse-power is the unit of work done or capable of being done by steam or water flowing in a pipe.

To find the number of *watts* a current of electricity develops multiply the amperes (quantity)

by the volts (pressure). Seven hundred forty-six watts are equal to one horse-power.

- (4) When electricity is forced through a wire the wire opposes the passage of the current; this is called the *resistance* of the wire and resistance is measured in *ohms*. It is just the same with water forced through a pipe for the size of the pipe and the friction due to the water rubbing along the pipe offers a resistance to the flow of the water.

A Long Distance Transmitter.—In up-to-date wireless stations transformers have taken the place of induction coils which were formerly used and alternating current is employed to operate the transformers wherever it can be had.

Where only direct current is to be had the transformer can also be used, but an *interruptor*, which will also be described, is required. So whether you have alternating or direct current, the transmitting apparatus is just the same—except for the *interruptor*.

When I say that this is a *long* distance transmitter, I mean *long* as compared with the one previously described. The United States Government will not grant a license to any boy whose station is fitted with a larger transformer than one kilowatt.¹

Unless you use a very large aerial, a $\frac{1}{2}$ kilowatt transformer will give you all the power you need and this is the size I have taken for this set. A $\frac{1}{2}$ kilowatt transformer will give you a sending radius of from 25 to 100 miles.

The different parts required for this transmitter are:

- (1) A *source of current* to operate the transformer,
- (2) A transformer for *stepping up* the low-pressure current of the lighting *mains*, which is about 110 volts, to a high-pressure alternating current of about 10,000 volts,
- (3) A *resistance* for regulating the amount of current supplied by the alternating current mains to the transformer,

¹One kilowatt is equal to about $1\frac{1}{3}$ horse-power.

- (4) A *telegraph key*, for making and breaking up the alternating current which supplies the transformer into the Morse code of dots and dashes,
- (5) A *condenser of Leyden jars* which is charged by the high-pressure currents set up by the transformer and which discharges through
- (6) A *spark-gap* and so sets up sparks, and
- (7) A *tuning coil* through which the high-frequency currents set up by the spark-gap surges into the *aërial* and *ground*.

If a *direct current* is used then

- (8) An interruptor will be needed to make and break the current in the primary coil.

The Source of Current.—To obtain an electric current sufficient to operate a transformer, the current should be taken from the *mains* of an electric light or power plant.

A battery powerful enough to work a transformer would be very costly to buy and to keep up. For this reason it is assumed that you have electric current for lighting purposes in your operating room.

In Fig. 47, page 43, a picture is shown of a pipe and a valve which resemble a battery connected with a coil of wire and a telegraph key. In these cases the current of water or of electricity always flows in the same direction.

An alternating current is different from a direct current in that it changes its direction 120 times a second, more or less.

In a piston pump every time the *piston* moves *up* the water will be forced through the coiled pipe in one direction, and every time the piston moves *down* the water will flow in the other direction, so that if the piston is moved up and down like a pump-handle when pumping water, the water in the pipe will move first in one direction and then in the other direction regularly. In other words the water in the pipe will *alternate* in direction.

This is also true of an alternating current of electricity and a machine for producing alternating currents, called a *generator*,

is so built that the current changes its direction 120 times a second, or makes 60 complete *reversals*, or *cycles* as it is called, a second. A diagram including a generator, a primary coil of a transformer and a key is shown in Fig. 61.

The Transformer.

—A transformer for using alternating current is even a simpler piece of apparatus than an induction coil, since it does not have an interruptor.

A transformer comprises three parts, and these are (a) a core, (b) a primary coil, and (c) a secondary coil.

The core is formed of pieces of thin sheet-iron. See Fig. 189, page 171.

A primary coil of heavy insulated wire is slipped over the *leg* of the core, the ends of the coil leading to a pair of binding posts mounted on the cheeks of the coil so that a connection can be made with the *regulating resistance* and one of the wires of the lighting mains. The secondary coil of fine wire is slipped over the other *leg* of the core and the ends of the coil are connected with the battery of Leyden jars. See Fig. 88, page 76.

The size of this transformer is about 6 inches high, $9\frac{3}{4}$ inches wide and $11\frac{3}{4}$ inches long. It weighs about 25 pounds and is *rated* at $\frac{1}{2}$ kilowatt, about $\frac{7}{10}$ of a horse-power.

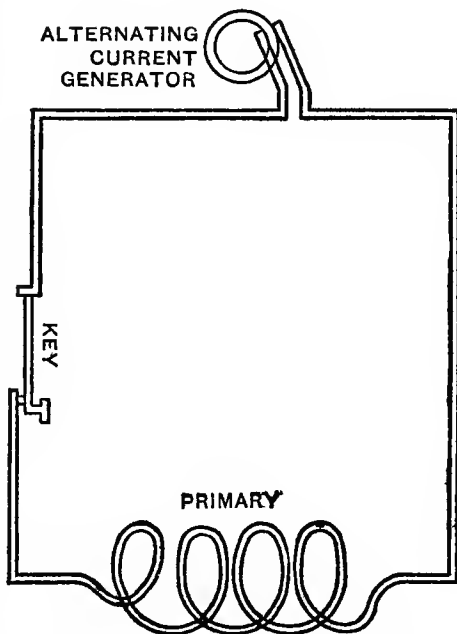


FIG. 61.—DIAGRAM OF ALTERNATING CURRENT CIRCUIT.

A complete description of how to construct a $\frac{1}{2}$ kilowatt transformer is given on page 171, Chapter I, Part III.

The Key.—A key having large contacts is required for breaking the current that *feeds* the primary coil of the transformer where upwards of 10 amperes are used.

A good substantial key can be made by following the drawings shown in Figs. 63, 64 and 65. The base is a block of wood 3 inches wide, 6 inches long and $\frac{3}{4}$ inch thick.

The *supports* which hold the lever up off the base are pieces of brass about $\frac{1}{8}$ inch thick, $\frac{3}{4}$ inch wide and 1 inch high. The lower end is bent over $\frac{1}{4}$ inch while in the upper end of each support there is drilled a $\frac{1}{8}$ inch hole and through the lower edge two $\frac{1}{8}$ inch holes are drilled as shown in Fig. 62.

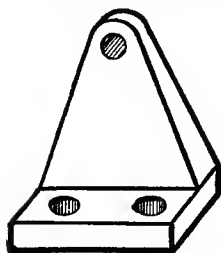


FIG. 62.—SUPPORT FOR KEY.

The lever, shown in Figs. 63 and 64, is a straight bar of brass $\frac{3}{8}$ inch thick, $\frac{1}{2}$ inch wide and 5 inches long. A $\frac{1}{8}$ inch hole is drilled through each end of the lever, one for the adjusting screw (see Fig. 63) and the other for the screw holding a silver contact disk on one side and a hard rubber button on the other side. A $\frac{1}{8}$ inch hole is also drilled through the thin side of the lever and at a distance of $1\frac{1}{2}$ inches from the end in which the adjusting screw is placed. This hole is for the screw that holds the lever between the supports. All these holes are to be tapped with what is called 8-32 tap (see Appendix C); that is threads have to be cut in the brass where the holes are drilled.

The upper silver contact disk (see Fig. 63) is soldered to the head of a flat-headed machine screw which is screwed through the lever and into the hard rubber button. The lower silver contact disk is also soldered to a flat-headed machine screw, a washer is put on and the screw set in a hole in the wood base. In the bottom of the base a hole $\frac{5}{8}$ inch in diameter is bored halfway through to meet the hole in which the contact screw is set and on the bottom of the screw is placed a nut. The silver

disks, which are about $\frac{1}{32}$ inch thick and $\frac{1}{2}$ inch in diameter, may be bought of almost any jeweler for about a quarter, while the

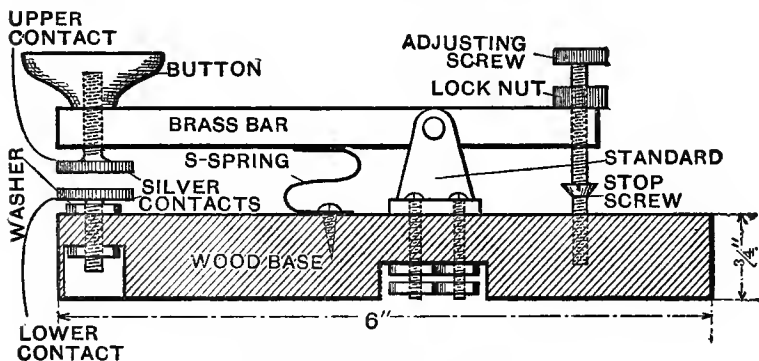
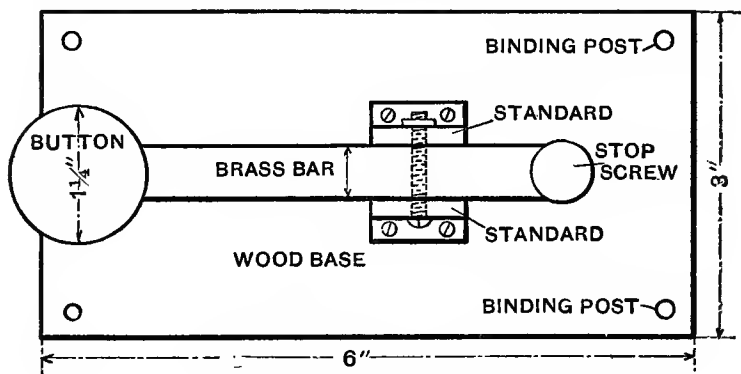


FIG. 63.—SIDE VIEW OF KEY.

hard rubber button may be bought from a dealer in electrical supplies for about 6 cents.

The brass supports are held to the base by machine screws



[FIG. 64.—TOP VIEW OF KEY.

with nuts put on them, a hole being bored out of the bottom of the base for this purpose. The lever is held in place between the brass supports by a machine screw as shown in Fig. 64. The S spring is made of a strip of spring brass and is screwed to

the base but not to the lever. A flat-headed machine screw is screwed through the back of the base under the adjusting screw and serves as a *stop* for the lever, that is it prevents the front end of the lever from flying up when released. Finally two binding posts are screwed on the back of the base.

The lever is connected with one of the binding posts by a piece of insulated wire hooked around one of the screws which

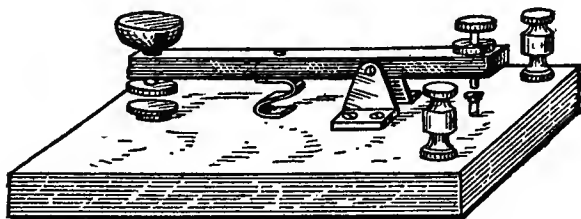


FIG. 65.—KEY COMPLETE.

holds the supports to the base, as shown in Fig. 63. The lower contact is connected to the other binding post, but this connection is not shown. Fig. 65 shows the key complete.

The Water Resistance.—Where an alternating current is used, some means must be provided to allow a certain amount of current, which must be neither too large nor too small, to flow into the primary coil of the transformer.

The amount of current depends upon the size, or *capacity*, as it is called, of the Leyden jars. If the primary current is larger than the jars can take, the spark will be thin and red; if the current is too small, the spark will be weak. Hence a variable resistance is needed to get the amount of current that is exactly right for the capacity of the Leyden jars.

There are many ways to regulate the current flowing into the primary coil, but a water resistance is the easiest and cheapest to make. Take a gallon jar, either of glass or of earthenware, and make a wood cover to fit it as shown in Fig. 66, which is a cross-sectional view of the resistance.

On the wood cover screw two binding posts near the edge

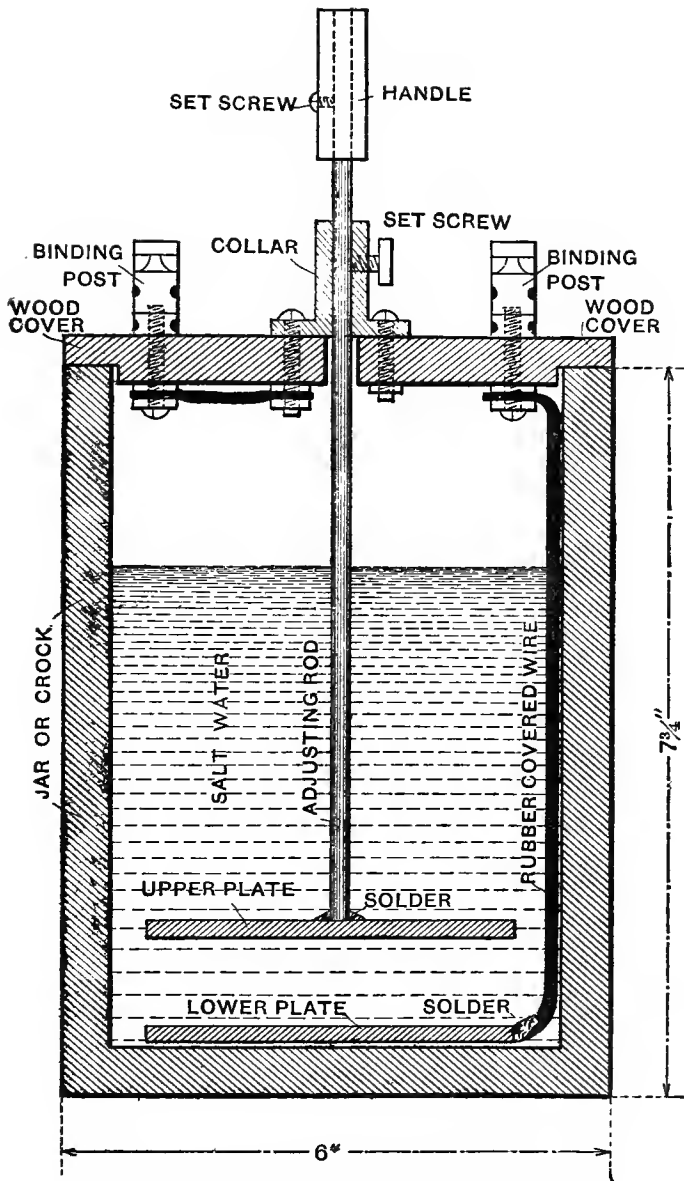


FIG. 66.—CROSS SECTION VIEW OF WATER RESISTANCE.

(see Figs. 66 and 67) and in the center screw on a brass *collar* having a *flange* and fitted with a *thumb screw*. This collar should have an inside diameter of $\frac{1}{4}$ inch, and be about $1\frac{1}{4}$ inches

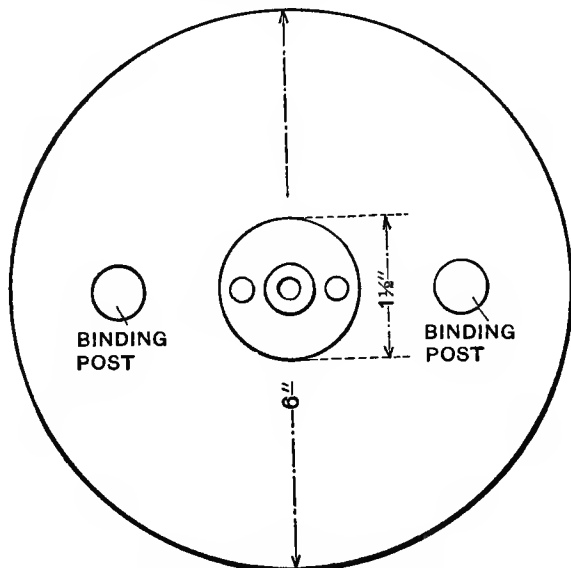


FIG. 67.—TOP VIEW OF WATER RESISTANCE.

high. It is shown full size in Fig. 68. It is connected with one of the binding posts by a bit of heavy insulated wire.

Now solder a disk of copper, or galvanized sheet-iron, of such size that it can move freely up and down in the jar, to one end of a brass rod $\frac{3}{16}$ inch in diameter and 4 inches longer than the height of the jar.¹ To another disk of copper, or galvanized iron, of the same size as the first, solder a piece of rubber-covered wire and after placing this disk in the bottom of the jar bring the wire up the side of the jar and connect the end with the other binding post.

¹As gallon jars vary in height and diameter, the length of this rod cannot be accurately given.

Pour $\frac{3}{4}$ gallon of water into the jar; throw in a handful of salt, and this piece of apparatus is ready for use.

The Condenser.—With an alternating current transformer the current at the ends of the secondary coil is so large that when the first spark passes, the current continues to flow across the gap in the form of a flaming arc.

To produce a succession of sparks a condenser is used and the Leyden jar condenser is one of the best known forms. When the current from the ends of the secondary coil charges the Leyden jars, these discharge across the spark-gap and this sets up high-frequency electricity.

To make a condenser get six half-gallon glass jars and a pound of *tin foil*. Clean and dry the jars thoroughly; next cut the tin foil into strips which will just cover the inside and the outside of the jars to within one-third of their tops. To fasten the sheets of tin foil to the jars get some shellac varnish and lay it on the inside of the jars first; take a sheet of tin foil and place it inside on the surface of one of the jars and rub out all the wrinkles and uneven places.

A circular sheet of tin foil must also be placed in the bottom so that it will overlap the sheet of tin foil around the inside. Next shellac the outside of the jar and cover it with tin foil the same way. When all the jars are done, shellac them all over, inside and out, glass and tin foil, several times, allowing enough time for them to dry after each coat is put on.

The covers for the jars should be made of wood and turned in a lathe to fit the necks closely. To each cover a binding post is screwed and to the screw of the binding post on the under side a thin brass spring is fastened as shown in the cross-section

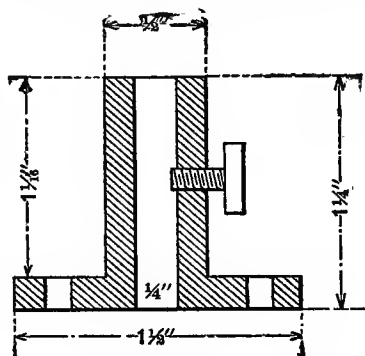


FIG. 68.—CROSS SECTION OF COLLAR.

tion view of Fig. 69, while Fig. 70 is a view of the spring in perspective. This spring will pass through the neck of the jar

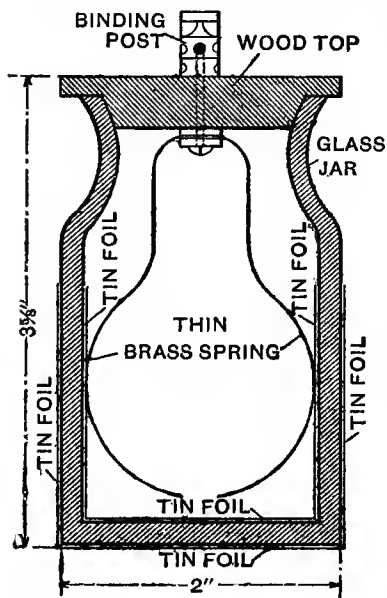


FIG. 69.—CROSS SECTION VIEW OF LEYDEN JAR.

and once inside will spring out and make a good contact with the inner coating of tin foil. Fig. 71 shows a Leyden jar complete. To hold the jars in position make a wood box 17 inches long, 12 inches wide and 6 inches high and screw on four porcelain insulators to the bottom. Solder a piece of wire to a sheet of zinc or brass, lay it in the bottom of the box and connect the wire to the screw holding a binding post to the outside of the box, as shown in Fig. 72.

The jars are set in the box on the sheet of zinc or brass and this connects all the outer surfaces of the jars together. The binding posts

on top of the jars are connected up with pieces of heavy insulated wire as shown in Fig. 72. By this arrangement any one or any number of jars can be *cut in* or *out* and this makes the Leyden jar condenser adjustable. Fig. 73 is a picture of the condenser complete.

The Spark-Gap.—A spark-gap apparatus to carry half a horse-power or more of electricity must be of goodly size or there will be a great loss of energy, due to overheating. A spark-gap for $\frac{1}{2}$ kilowatt set should be mounted on a slate or marble base $4\frac{1}{2}$ inches long, 3 inches wide and $\frac{1}{2}$ inch thick as shown in Figs. 74, 75 and 76.

Make two supports of brass rod $1\frac{1}{2}$ inches long, 1 inch wide

and $\frac{1}{2}$ inch thick, as in Fig. 77. Drill two holes in one end of each support and tap the holes to fit 8-32 machine screws which are to hold the supports to the slate base.

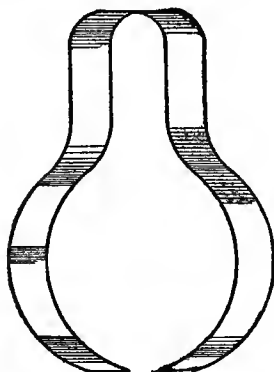


FIG. 70.—SPRING OF LEYDEN JAR.



FIG. 71.—LEYDEN JAR COMPLETE.

In one of the supports drill a hole $\frac{5}{16}$ inch in diameter and thread it with a $\frac{3}{8}$ inch tap cutting 18 threads to the inch to fit

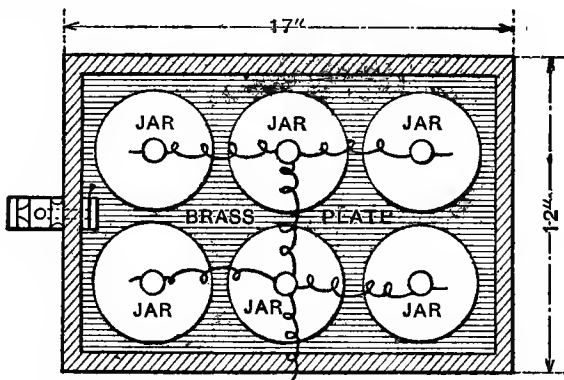


FIG. 72.—TOP VIEW OF LEYDEN JAR CONDENSER.

the adjusting screw, see Figs. 74 and 75. Cut a *slot* with a *hack saw* in the top of the support, down through the hole and

to $\frac{3}{8}$ inch below it. Through the upper end of the support, and at *right angles* to the big hole and the slot, drill a hole for a set

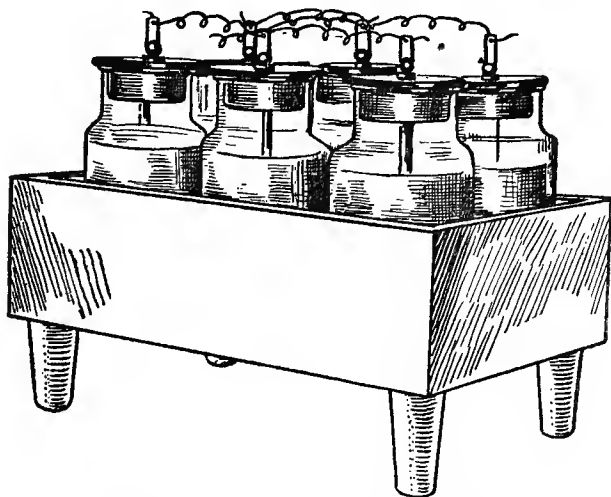


FIG. 73.—LEYDEN JAR CONDENSER COMPLETE.

screw. The purpose of the slot is to give plenty of freedom to the adjusting screw when needed and when the proper adjust-

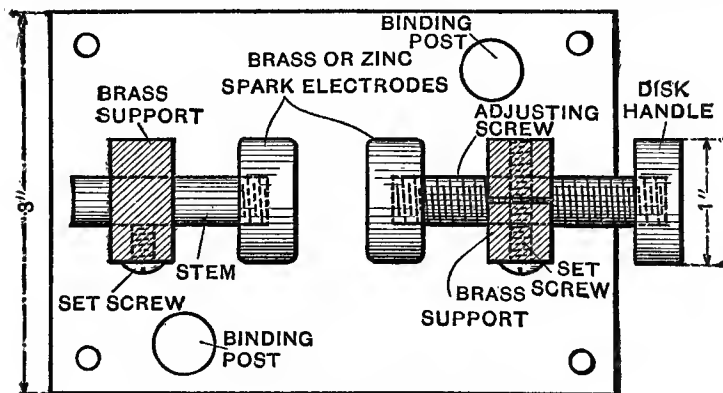


FIG. 74.—TOP VIEW OF SPARK-GAP.

ment has been made to permit the set screw to draw the ends of the support together and so hold the adjusting screw tight.

The other support is like the one just described except the

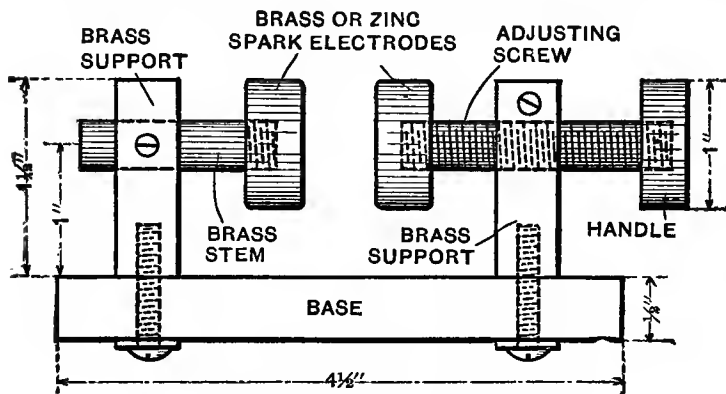


FIG. 75.—SIDE VIEW OF SPARK-GAP.

large hole near the top is $\frac{3}{8}$ inches in diameter and is *not threaded* and the set screw reaches through the support to the

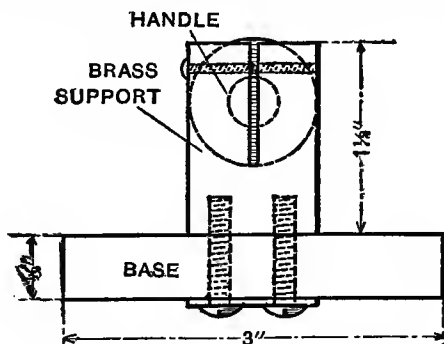


FIG. 76.—END VIEW OF SPARK-GAP.

hole only, as shown in Fig. 74. The two supports are now screwed to the base as shown in Figs. 75 and 76.

To make the adjusting screw cut a piece of brass from a

rod $\frac{3}{8}$ inch in diameter and $2\frac{1}{4}$ inches long, cut threads on this rod so that it will fit the threaded support. On one end of the adjusting screw, screw a disk of hard rubber or hard wood

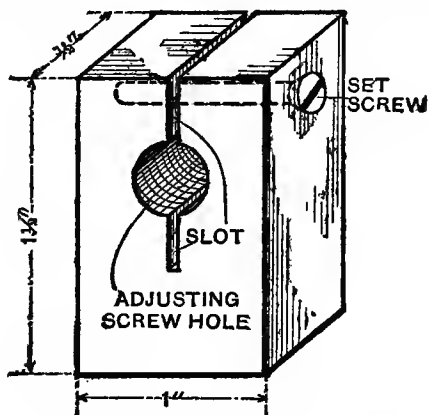


FIG. 77.—ADJUSTING SCREW SUPPORT.

$\frac{3}{8}$ inch thick and 1 inch in diameter, as shown in Fig. 78. Now screw the adjusting screw in the support. For the *stem* cut a piece of brass $1\frac{1}{2}$ inches long and thread it at one end; slip it

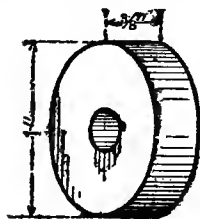


FIG. 78.—ADJUSTING HANDLE.

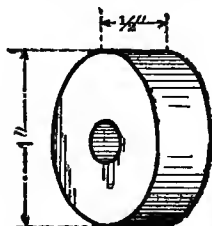


FIG. 79.—BRASS SPARK ELECTRODE.

through the hole in the other support and screw up the set screw, as shown in Fig. 74.

Make, now, two spark *electrodes* of brass rod 1 inch in diameter and $\frac{1}{2}$ inch thick and drill and tap threads in these (see Fig. 79) and screw one to the end of the adjusting screw and the

other to the end of the stem, and the spark-gap is completed as shown in Fig. 80.

The Tuning Coil.—This simple but important *device* is the chief means by which the transmitter is tuned and waves of the greatest force are sent out.

A tuning coil for sending is merely a large number of turns of heavy wire wound in a *spiral form* or *helix*, as it is called.

To make a tuning coil, cut out two disks of well-seasoned

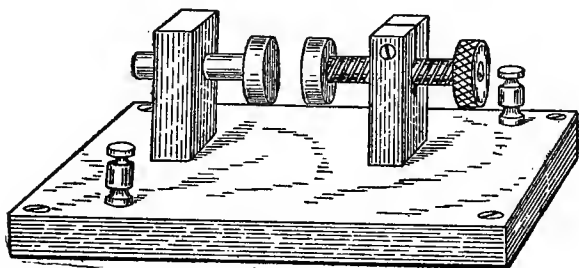
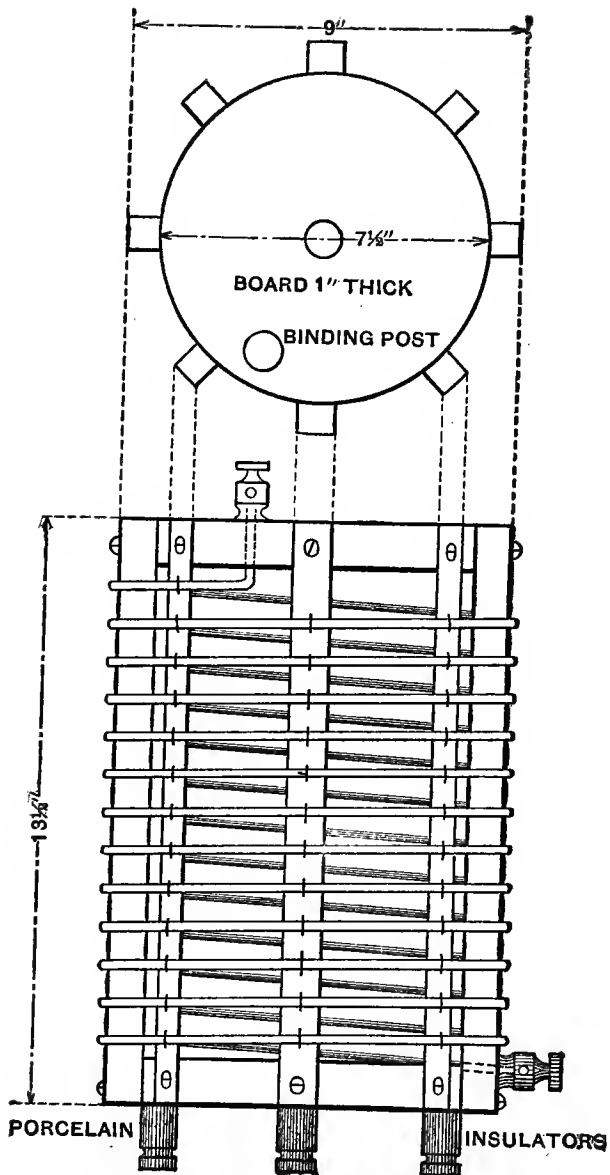


FIG. 80.—SPARK-GAP COMPLETE.

wood 1 inch thick and $7\frac{1}{2}$ inches in diameter. Screw on with round-headed wood screws to these disks 8 sticks of hard wood $\frac{3}{4}$ inch square and $13\frac{1}{2}$ inches long, as shown in Figs. 81 and 82 and so forming a sort of drum.

Next get 32 feet of brass wire $\frac{1}{4}$ inch in diameter and wind it on a form made of wood that is about 7 inches in diameter so that the turns of wire are close together. When the wire is taken off this form and placed over the drum it will be found to fit it snugly. Turn up one end of the wire and cut threads on the end so that a binding post can be screwed on to it. Thread the other end the same way. Pass the bent end through a hole in the top of the disk as shown in Fig. 82, screw on the binding post and slip the other end through a hole in one of the lower strips and screw on another binding post.

To hold the wire in place drive *insulated staples* over the turns of wire where they cross the strips. Finish the tuning coil by screwing on to the bottom three blocks of wood, or better,



FIGS. 81 and 82.—TOP AND SIDE VIEW OF TUNING COIL.

porcelain knobs, for legs, all of which is shown clearly in Figs. 83 and 85.

To connect the coil with the other parts of the apparatus and with the aërial wire make three clips of brass as shown in Figs. 83 and 84. Cut six strips of spring brass $\frac{3}{8}$ inch wide and 2 inches long as shown in Fig. 83; bend the end of each piece to fit the wire of the coil and place the straight ends of a pair of these pieces on opposite sides of a thin piece of wood, *hard fiber* or brass and drill a hole through them for a small machine screw; push this screw through the pieces and screw a small

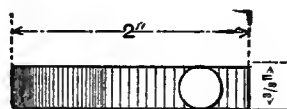


FIG. 83.—TOP VIEW OF SPRING CLIP.

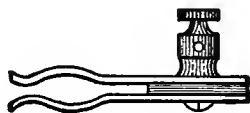


FIG. 84.—SIDE VIEW OF SPRING CLIP.

binding post on tight as shown in Fig. 84. The coil complete is shown in Fig. 85.

Connecting up the Apparatus for Alternating Current.—

Having all of the parts of the transmitter at hand, lay them out on your operating table somewhat after the plan shown in Fig. 86. It really doesn't matter just how the different parts are placed on the table, though the key should be conveniently near the right-hand lower corner and the water resistance close to it on the right-hand side so that the current can be *varied* easily.

The transformer may set well back and the spark-gap can be screwed to the wall where its action can be easily seen and yet be well out of the way. This will be better than to have it screwed to the table in the position shown. The tuning coil should be set so that the clips can be changed from one turn of wire to another easily. The condenser will seldom have to be touched.

In bringing in the electric light *leads* see that they are properly put up in accordance with the Fire Underwriters' Rules

which will be found in full in Book III, Chapter III, page 199.

While all of the connections are shown in the plan view

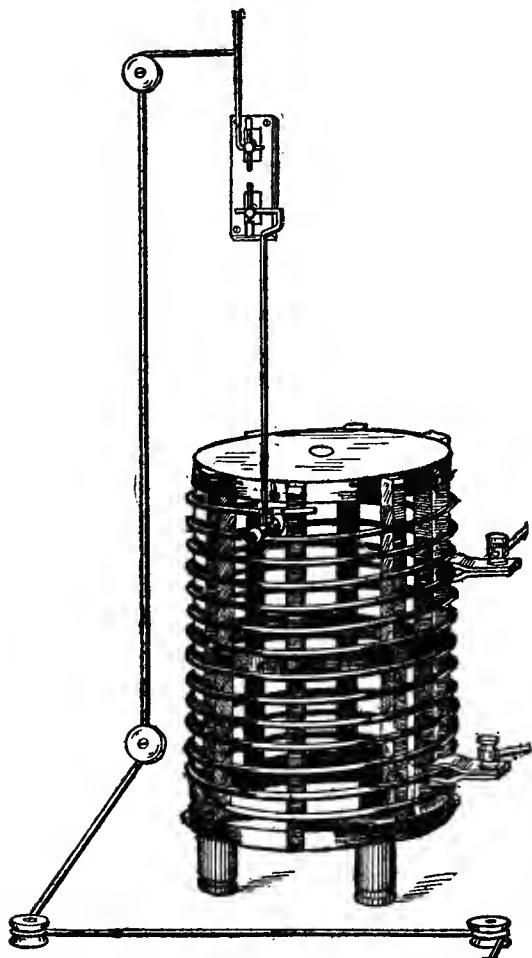


FIG. 85.—TUNING COIL COMPLETE.

Fig. 86, the *wiring* diagram, Fig. 87, gives a clearer idea of the connections. For wiring up the different parts, use No. 12

or 14 insulated electric light wire. The transmitter complete is shown in Fig. 88.

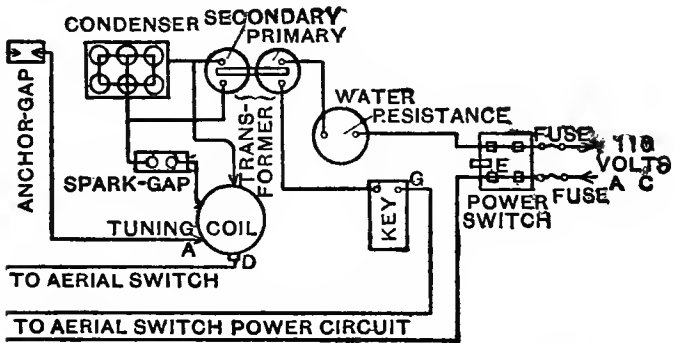


FIG. 86.—PLAN VIEW OF INSTRUMENTS ON TABLE.

Connecting up the Apparatus for Direct Current.—Where direct current only is to be had an *electrolytic interruptor* must

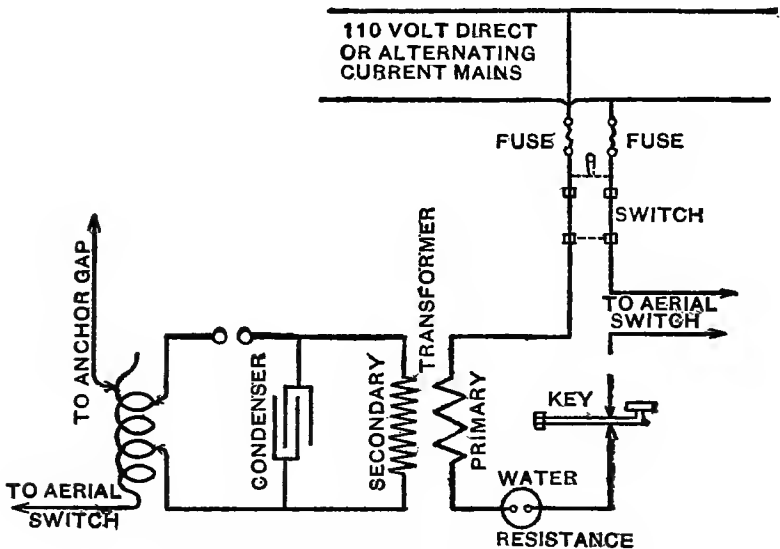


FIG. 87.—WIRING DIAGRAM OF CONNECTIONS.

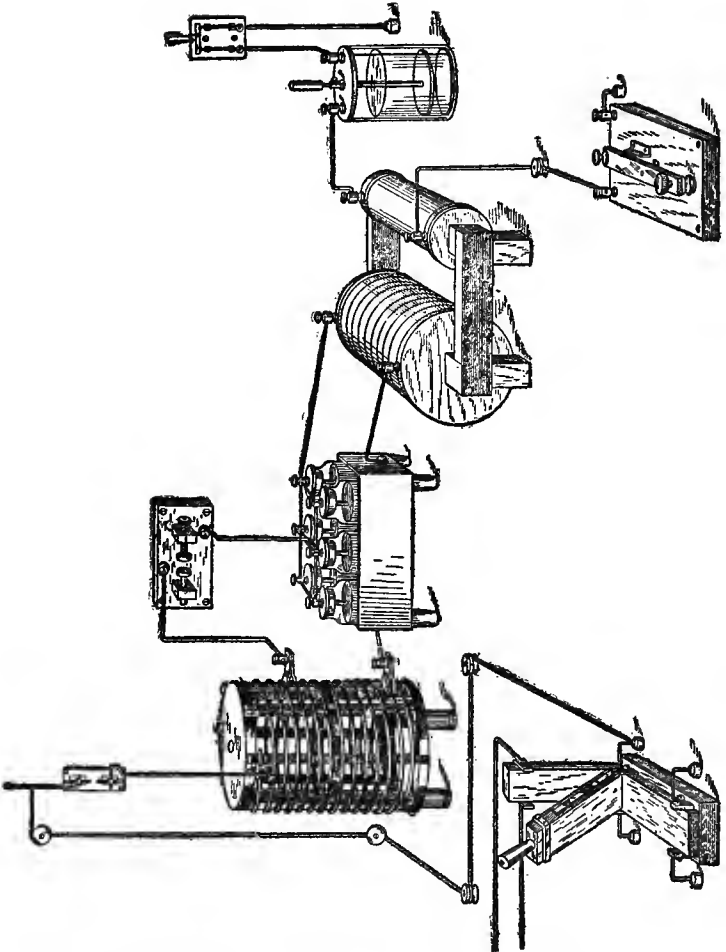


FIG. 88.—TRANSMITTER COMPLETE AND READY FOR SENDING.

be used to operate the transformer. When an electrolytic interruptor is used the water resistance is not needed, as the amount of current can be varied by adjusting the interruptor.

The interruptor is connected in the primary circuit exactly the same way as the water resistance so that no change in the wiring need be made. The construction of an electrolytic interruptor is given in Part III, Chapter II, page 191.

Adjusting the Transmitter.—After the apparatus is set up and connected with the aerial and ground raise the upper plate of the water resistance to nearly the top of the water so that the resistance will be high and hence keep too large a current from flowing through the primary of the transformer.

Have about four of the six Leyden jars connected together and set the spark-gap *electrodes* so that the gap is about $\frac{1}{2}$ inch long. Now close the switch in the main line circuit, close the key and watch the spark-gap. If no sparks pass, open the switch and let the plate down in the water a little farther. Repeat this operation until a good spark takes place in the gap.

When too much current flows in the primary of the transformer the spark will be red and stringy, and when this is the case use either less current or connect in more Leyden jars. The larger the number of Leyden jars the greater the amount of current which flows in the primary coil. When the current and the Leyden jars have been adjusted so that a good, white, snappy spark results, the switch is again opened and the spark-gap electrodes are *separated* until the gap is about $\frac{1}{2}$ inch wide.

Now change the position of the clips on the tuning coil, that is those clips which connect with the spark-gap and condenser until the longest sparks possible take place in the gap when the apparatus is roughly tuned.

A much better and easier way to adjust and tune the apparatus is to use a *hot-wire ammeter* and this piece of apparatus is described in Chapter IV, Part II, page 146.

COST OF TRANSMITTER WHEN BOUGHT OF DEALERS¹

1 $\frac{1}{2}$ kw. transformer.....	\$20.00
1 regulating resistance	6.00
1 telegraph key.....	4.50
1 switch (double pole).....	.50
1 tuning coil	10.00
1 condenser of 6-one-gallon or 12 half-gallon jars..	15.00
1 spark-gap	5.00
1 fuse block .....	.25
1 roll of electric light wire.....	.50
1 dozen porcelain insulators.....	.25
<hr/>	
Total	\$62.00

COST OF TRANSMITTER WHEN HOME MADE

 $\frac{1}{2}$ kw. transformer²

17 pounds sheet iron @ 6c.....	\$ 1.02
3 pounds No. 13 double cotton-covered magnet wire @ 35c.....	1.05
5 pounds No. 34 double cotton-covered magnet wire @ \$1.10.....	5.50
10 yards empire cloth.....	5.00
Base for coil.....	.25
2 binding posts.....	.20
<hr/>	
Total	\$13.02

Water Resistance

1 1-gallon jar or crock.....	\$.10
2 dishes of zinc or brass.....	.25
1 brass collar with set screw.....	.50
2 binding posts .....	.20
1 brass rod .....	.25
<hr/>	
Total	\$1.30

¹The prices of the various parts of the apparatus as given below are only approximate and it is well to get prices from a number of dealers before buying.

²A full description with drawings for making a $\frac{1}{2}$ kilowatt transformer is given in Chapter I, Part III, page 153.

Telegraph Key

Wood base	\$.10
Brass bar .....	.20
Adjusting screw .....	.10
2 supports .....	.30
Button .....	.10
2 silver contacts.....	.25
Screws .....	.05
2 binding posts.....	.20
Switch double pole.....	.50
Fuse block .....	.25
<hr/>	
Total	\$2.05

Leyden Jar Condenser

6 1-gallon glass jars.....	\$.50
1 pound tin foil.....	.60
6 turned wood covers.....	.30
7 binding posts .....	.70
1 pint of shellac varnish.....	.10
Sheet brass for springs.....	.25
Wood box	1.00
<hr/>	
Total	\$3.45

Tuning Coil

2 wood dishes (top and bottom).....	\$.20
8 wood strips 13½ inches long.....	.25
32 feet of ¼-inch brass wire.....	1.50
Brass wood screws.....	.10
Insulated staples .....	.20
3 porcelain insulators .....	.06
4 binding posts .....	.40
Spring brass for clips.....	.15
Flexible lamp cord for clips.....	.50
<hr/>	
Total	\$3.36

Spark-Gap

1 slate base	\$.25
2 brass supports cut and threaded.....	.50
1 adjusting screw threaded.....	.25
1 stem (threaded) .....	.15
1 hard rubber handle.....	.25
2 iron electrodes drilled and tapped.....	.50
2 binding posts .....	.20
	<hr/>
Total	\$2.10
Roll of electric light wire.....	.50
1 dozen porcelain insulators.....	.30
	<hr/>
Total cost of transmitter.....	\$26.02

CHAPTER II

THE RECEPTOR

A good wireless receptor which will give you a lot of pleasure and service can be easily made—except the head telephone receiver—by following the drawings and descriptions given in this chapter.

While this *receptor* is not the best that can be made, still messages up to 500 miles or so can be received with it, the distance, of course, depending upon the length and height of your aërial, the power of the sending station and the adjustment of the apparatus.

There are a large number of wireless boys who have only a receiving apparatus connected with their aërials, and although they cannot send messages they can receive them from any station within their range.

The Government has a great wireless station at Arlington, Virginia, which has a sending range of over 3,000 miles and there are other Government stations scattered all over the United States, all of which send out the standard time daily and if you live within signaling range of one of these stations you can receive the correct time every day without cost. A Government license is not required where only a receiving set is used.

The various parts needed for a receiving set are:

(1) A *tuning coil*, for tuning the aërial wire so that waves of only a given length can be received. Thus any station can be *tuned in or out* as desired.

(2) A *crystal detector*, for changing the high-frequency currents which surge in the aërial wire and tuning coil into a direct current, capable of operating the telephone receiver.

(3) A *small condenser*, which with the tuning coil and the detector forms a closed circuit.

(4) A *telephone receiver*, for changing the direct current passing through the detector into sound waves so that the ear hears them as dots and dashes.

(5) An adjustable resistance, called a *potentiometer*, for

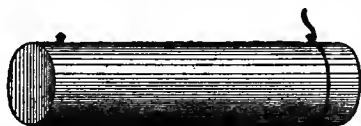


FIG. 89.—WOOD CORE OF TUNING COIL.

regulating the amount of current flowing through the detector from a dry cell.

(6) A *dry cell* for producing the current which flows through the detector, and

(7) A *small switch*, for opening and closing the dry cell circuit.

The Tuning Coil.—For this receptor you can use either (1) a *close-coupled* tuner, or (2) a *loose-coupled* tuner. The first kind is the easiest to make and you can tune in or out the waves of sending stations, but the second kind tunes the sharpest and gives the best results generally.

A Close-Coupled Tuning Coil.—This tuner is made with three sliding contacts and consists of a frame which holds:

(1) A core made of a cylinder of wood or a piece of glass tubing on which is wound (2) a single layer of insulated wire, the insulation being scraped off on three sides of the coil so that (3) the brass sliders whose springs make contact with the turns of wire can be moved freely back and forth over them.

To make the tuning coil get a wood worker to turn for you a cylinder of well-seasoned hard wood $8\frac{1}{2}$ inches long and $2\frac{3}{4}$ inches in diameter and boil it in paraffin.

In this cylinder $\frac{1}{2}$ inch from each end put a small wood screw as shown in Fig 89, when it is ready for the wire. The

best kind of wire for this purpose is known as *enameled wire*, but if you cannot get this easily use double cotton-covered magnet wire. A $\frac{1}{2}$ pound of No. 32 wire, Brown and Sharpe gauge, will be enough of either kind.

Before you begin to wind the wire on the cylinder, twist an

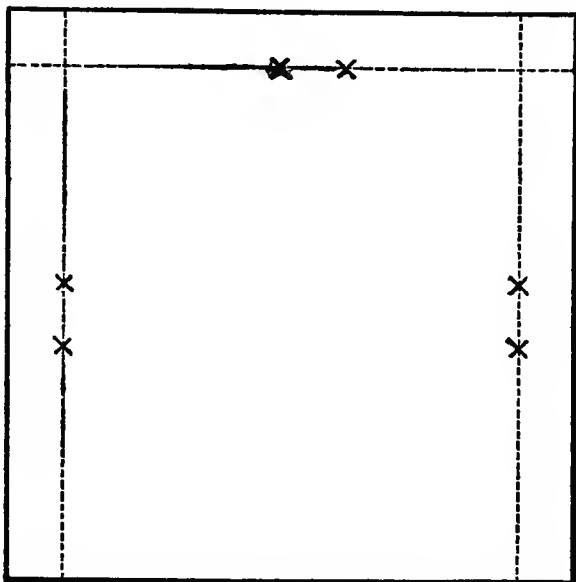


FIG. 90.—CHEEKS OF COIL.

end of the wire around one of the screws and put the screw in tight with a screw-driver as this end is not to be connected with anything. As you wind on each turn of wire, draw it tight and press it up close to the last turn. When you have wound on enough wire so that the turns reach the screw at the other end, twist the wire around the screw and drive it down tight, but do not cut the wire off short, for this end is to be connected with a binding post.

If cotton-covered wire is used it should be well shellacked

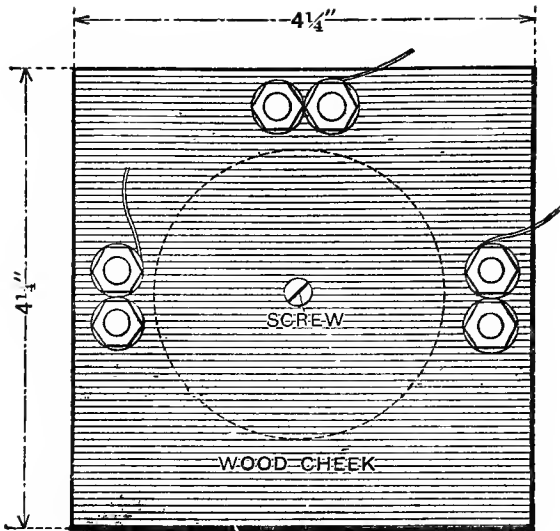


FIG. 91.—END VIEW OF TUNING COIL.

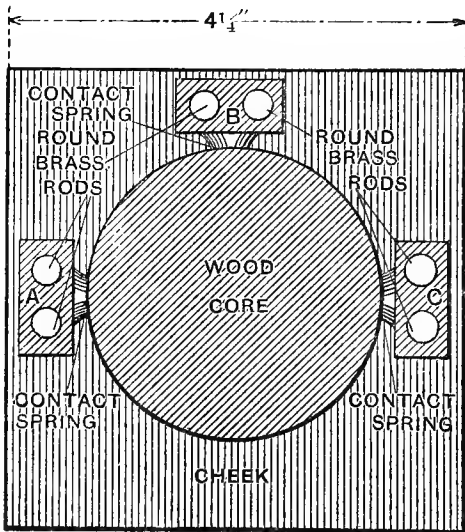


FIG. 92.—CROSS SECTION OF TUNING COIL.

and allowed to dry before assembling. But whether the wire is enameled or cotton-covered the insulation must be scraped off on a line $\frac{1}{2}$ inch wide and the whole length of the coil on the three sides where the springs of the sliders are to make contact with the wire.

With enameled wire this is an easy thing to do and a neat job will result, but with cotton-covered wire it is not so easy and a poor-looking job is likely to come of it. For this reason it is better to use enameled wire if it can be had.

The cheeks of the coil, as the wooden ends are called, are next in order. These should also be made of well-seasoned hard wood and should be $4\frac{1}{2}$ inches square and $\frac{3}{4}$ inch thick. Now on each of the three sides draw a line $\frac{3}{8}$ inch from the edge as shown in Fig.



FIG. 93.—BINDING POST WITH WOOD SCREW.

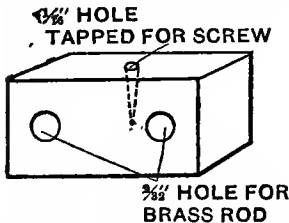


FIG. 94.—SLIDES FOR TUNING COIL.

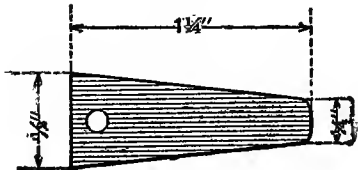


FIG. 95.—BRASS PLATE FOR CONTACT SPRING.

90 by the dotted lines. Measure from the middle of these lines $\frac{1}{4}$ inch each way, and make a point with a pencil and drill a hole $\frac{3}{8}$ inch in diameter. This will make six



FIG. 96.—CONTACT SPRING FINISHED.

holes, two on each side and the holes on each side will be $\frac{1}{2}$ inch apart, from center to center, all of which is clearly shown in Figs. 91 and 92.

Smooth the cheeks up with sandpaper and give them a coat of shellac varnish, and when dry screw them to the ends of the wooden coil with a wood screw and see

that the coil is exactly in the centers of the cheeks as shown in Figs. 91 and 92. On the edge of the cheek nearest the free end of the wire on the core put in a binding post having a wood screw on its base, as shown in Fig. 93.

Having made all of the easy parts of the coil you will now come to something a little harder—in metal. Get six pieces of round brass rods each of which is $10\frac{3}{4}$ inches long, and $\frac{1}{4}$ inch in diameter; cut threads on the ends of these rods about $\frac{3}{4}$ inch

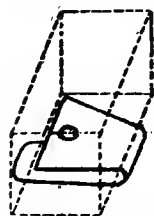


FIG. 97.—CONTACT SPRING ON SLIDER.

down and get 24 washers large enough to slip over the rods, and 12 brass nuts to fit the threads cut on the rods.

The next and last thing to do is to make the sliding contacts. These *sliders*, as they are called, are made of brass. Get three pieces of brass $\frac{1}{2}$ inch square and 1 inch long, as shown in Fig. 94, and drill two holes in each one $\frac{3}{8}$ inch in diameter and so that the centers of the holes are exactly $\frac{1}{2}$ inch apart.

These holes will have to be drilled very true or the sliders, when they are put on the rods, will not run smoothly.

Drill and tap a $\frac{1}{8}$ inch hole in each slider between the larger holes but on a side at right angles to them as shown in Fig. 94. Spring brass will do for the springs which make contact with the wire of the core but springs made of phosphor-bronze are better. Make three springs of sheet brass or phosphor-bronze $1\frac{1}{4}$ inches long, $\frac{1}{2}$ inch wide at one end and $\frac{1}{4}$ inch wide at the other end, as shown in Fig. 95; screw each spring to a slider and bend it over as shown in Fig. 96. Drill a $\frac{1}{8}$ inch hole through the wide end of the spring and screw it to the brass slider block as shown in Fig. 97.

The next step is to put the tuning coil together. Slip a pair of the brass rods through the holes in each of the sliders and push the ends of the rods through the cheeks of the coil, when the contact springs should rest on the turns of wire where the insulation has been scraped off. Next slip a pair of washers over the ends of each rod and screw on the nuts.

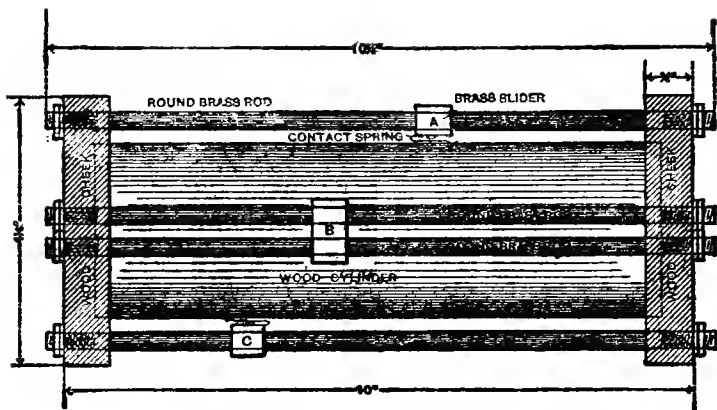


FIG. 98.—TOP VIEW OF TUNING COIL.

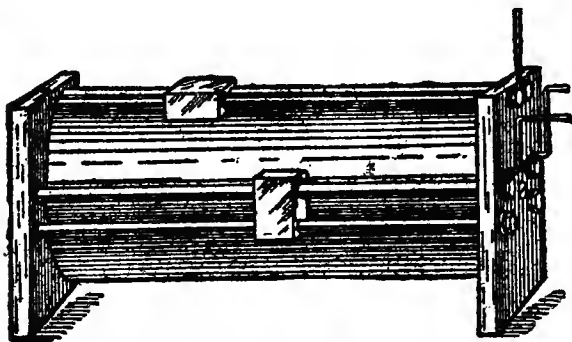


FIG. 99.—RECEIVING TUNING COIL COMPLETE.

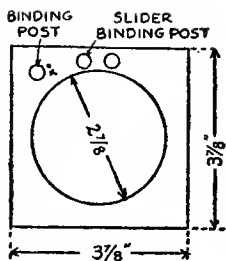
Before tightening up the nuts cut off three pieces of heavy insulated wire about 4 inches long and after scraping the ends bright loop them around the rods between the washers as shown in Figs. 91 and 99. These wires are to connect the sliders with the ground, the condenser, and the detector as shown in the plan and the wiring diagrams, Figs. 127 and 128. Fig. 98 shows a top view of the completed tuning coil, the cheeks being drawn in cross section to show the rod a little better. The tuning coil complete is pictured in Fig. 99.

The Loose-Coupled Tuning Coil.—For this tuner you will need: (1) a board for the base about 5 inches wide and $13\frac{1}{2}$ inches long; (2) two wood cheeks 4 inches on the sides for the primary coil; (3) two brass rods $\frac{1}{4}$ inch in diameter, and $6\frac{1}{2}$ inches long and threaded on both ends; (4) a pasteboard or fiber tube $5\frac{3}{4}$ inches long and whose wall is not more than $\frac{1}{8}$ inch thick; (5) two circular wood cheeks $2\frac{1}{8}$ inches in diameter for the secondary coil; (6) a pasteboard or fiber tube having an outside diameter of $2\frac{3}{8}$ inches and a length of 5 inches; (7) two brass rods $\frac{1}{4}$ inch in diameter and $13\frac{1}{2}$ inches long, threaded on both ends, for the secondary coil to slide on; (8) one 7-point adjustable switch; (9) about $\frac{1}{4}$ pound of No. 20 Brown and Sharpe gauge enameled copper wire for the primary coil; and (10) about the same amount of No. 26 Brown and Sharpe enameled copper wire for the secondary coil.

To assemble the tuner, begin by giving the large tube a couple of coats of shellack varnish, then wind on one layer of the No. 20 wire, and scrape off the insulation $\frac{3}{8}$ inch wide and the length of the coil; this is so that the slider can make contact with the successive layers of wire. One of the cheeks must have a hole sawed in it the diameter of the outside of the tube as shown at A in Fig. 100.

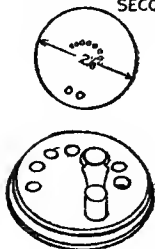
Now smear glue on one end of the tube and set it in the hole in the cheek; then thread one end of the wire through the small hole, marked x, in the other cheek, smear some glue on the other end of the tube and set it on the cheek and let it dry.

Next make a slider with a spring contact as I described for the close-coupled tuner; slip it over the guide rods and push the

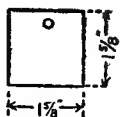


A-CHEEKS OF THE PRIMARY COIL

C-CHEEKS OF THE SECONDARY COIL

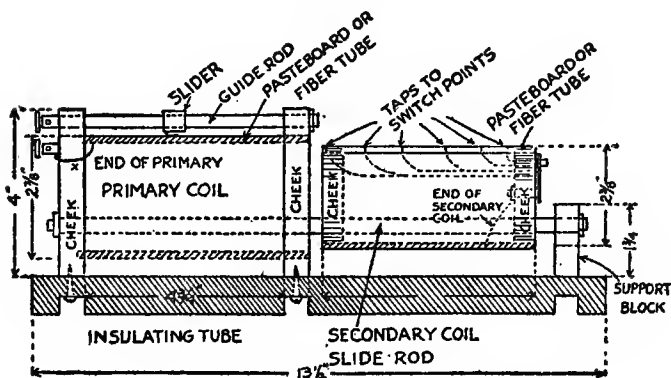


D-7 POINT CONTACT SWITCH



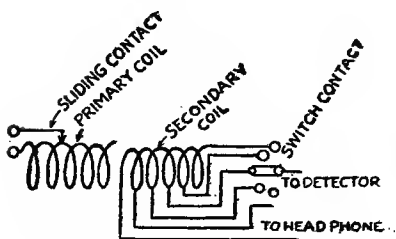
F-SUPPORT BLOCK FOR THE SECONDARY COIL

1.

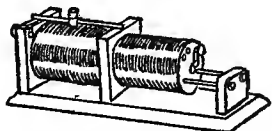


B-CROSS SECTION OF THE LOOSE COUPLER

2.



E-WIRING DIAGRAM OF A LOOSE COUPLER



G-THE LOOSE COUPLER COMPLETE

3.

4.

Fig. 100.—HOW THE LOOSE COUPLER IS MADE.

1. Parts of the Loose Coupler. 2. Cross Section of the Loose Coupler, 3. Diagram of Wiring of Loose Coupler. 4. The Complete Loose Coupler.

ends of these through the holes in the cheeks at the top as shown at *A* and *B*. Screw a binding post on one end of one of the guide rods and screw nuts on the other ends of them. This done set the primary coil on the base so that the end with the binding post in it will come to within $\frac{1}{2}$ an inch of the end of the base. Then screw them together, and the coil will be rigidly secured to the board.

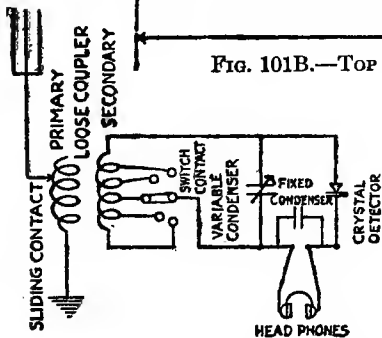
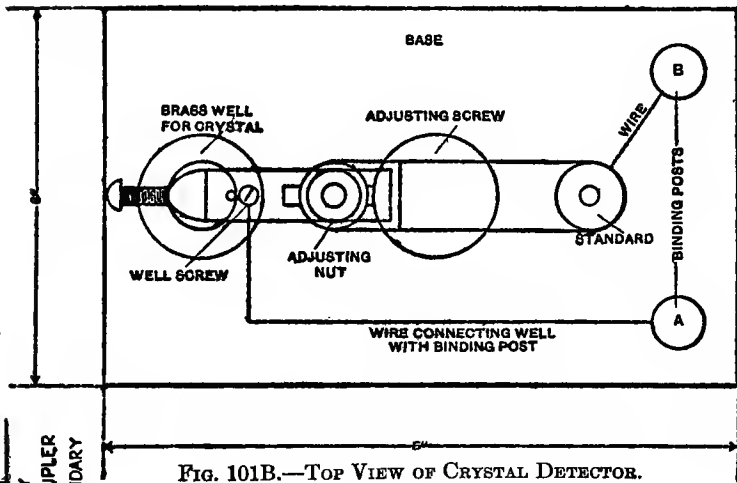
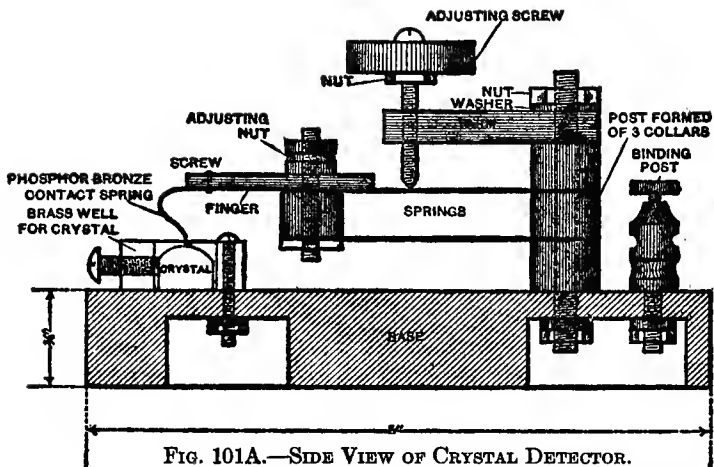
The primary coil completed, shellack the other paper or fiber tube and wind it with one layer of the No. 26 wire. Bring the ends of the wire inside the tube and count off the turns into five equal parts; scrape each of the equidistant turns, solder a wire to each one and bring it through to the inside of the tube as shown at *B*. Thread the seven ends of the wires through the little holes in the circular cheek (see *C*), and fasten each one to one of the contact points of the switch (see *D*), all of which is clearly shown in the wiring diagram at *E*. Now screw the switch to the cheek and then glue both cheeks in the ends of the tube.

Finally screw the support block, *F*, on to, and $\frac{1}{2}$ an inch from, the end of the base-board and slip the rods that are to support the secondary coil through the holes in the support block, thence through the holes in the cheeks of the secondary coil and on through the holes in the last cheek of the primary coil. Screw a nut on each end of the support rods and your loose tuner, which will look like *G*, is ready for service.

The Crystal Detector.—This detector is a good one in that it is simple in design, there is nothing to get out of order, its adjustment is fine enough for all ordinary working and it is almost as sensitive without using a dry cell as it is with one.

While it is not absolutely necessary, it is a good plan to enclose the detector in a box or case, except the adjusting knob. This will protect the crystal from the action of the air and moisture. You can easily do this by making a box of thin wood and fitting a glass top on it so that you can see the crystal.

The base of the detector may be made of a good piece of seasoned wood but slate or marble is better as these last materials are better insulators. Whatever material you use get a piece 3



inches wide, 5 inches long, and $\frac{1}{2}$ or $\frac{3}{4}$ inch thick. Drill three $\frac{5}{32}$ inch holes in the base, two for the screws of the binding posts and one for the support; now at exactly $2\frac{3}{4}$ inches from the center of the hole for the support drill a $\frac{3}{32}$ inch hole for the *well* screw as shown in Fig. 101.

On the under side of the base *ream* out these holes until they are $\frac{5}{8}$ inch in diameter and deep enough so that when the detector is put together the ends of the screws will not come below the bottom of the base. The top of the base should be perfectly smooth.

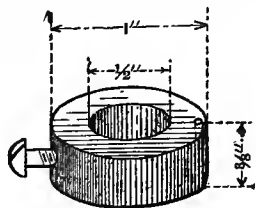


FIG. 102.—BRASS HOLDER OF CRYSTALS.

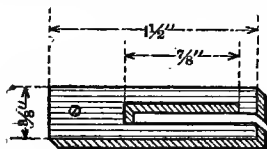


FIG. 103.—BRASS FINGER CONTACT.

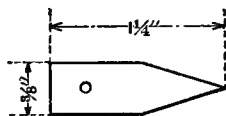


FIG. 104.—PHOSPHOR-BRONZE CONTACT SPRING (plate).

The purpose of the *well* is to hold any kind of a *crystal* tightly so that a good contact will be made. We will talk about the crystal presently. For the well cut a piece $\frac{1}{2}$ inch long from a brass rod 1 inch in diameter and drill a hole $\frac{1}{2}$ inch in diameter through it; also drill a $\frac{3}{32}$ inch hole parallel with the large hole through the rim so that the well can be screwed to the base as shown in Fig. 101; now drill and tap a hole through the ring and put in a machine screw as shown in Fig. 102.



FIG. 105.—PHOSPHOR-BRONZE CONTACT SPRING (bent).

Next take a strip of brass $1\frac{1}{2}$ inches long, $\frac{3}{8}$ inch wide and $\frac{1}{8}$ inch thick and saw out a slot in one end $\frac{7}{8}$ inch long and $\frac{5}{32}$ inch wide and drill a $\frac{1}{8}$ inch hole through the other end as shown in Fig. 103. This piece is called a *contact finger*. A piece of sheet phosphor-bronze $1\frac{1}{4}$ inches long and $\frac{3}{8}$ inch wide

with one end cut to a point and a hole drilled in the other end, as in Fig. 104, is secured to the end of the finger with a screw. This permits the point which makes contact with the crystal to

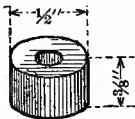


FIG. 106.—BRASS COLLAR.

be taken off if needs be. The point is then bent as in Fig. 105. The next step is to make four collars of round brass rod $\frac{1}{2}$ inch in diameter, $\frac{3}{8}$ inch long and drill holes through them $\frac{5}{32}$ inch in diameter as shown in Fig. 106. Three of these collars are used to form the support which holds the springs and *adjusting screw arm* in position and the fourth collar is used to separate the free ends of the springs as shown in Fig. 100.

The arm which holds the adjusting screw is made of a piece of brass $1\frac{3}{4}$ inches long, $\frac{1}{2}$ inch wide and $\frac{1}{4}$ inch thick; drill a hole in each end, make one of them $\frac{3}{32}$ inch in diameter and thread it and make the other $\frac{5}{32}$ inch in diameter and leave this one smooth. The arm is shown in Fig. 107.

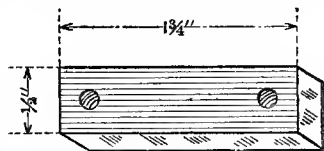


FIG. 107.—BRASS ARM FOR ADJUSTING SCREW.

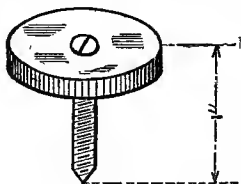


FIG. 108.—ADJUSTING SCREW.

The adjusting screw, Fig. 108, which fits into the threaded hole of the arm, is simply a machine screw $1\frac{1}{4}$ inches long with its end filed down to a point and having a disk of hard rubber, or of wood, 1 inch in diameter and $\frac{1}{16}$ inch thick forced on up to the head of the screw; a nut on the under side will keep it from slipping.

Make two stiff springs of spring brass $2\frac{1}{2}$ inches long, $\frac{1}{2}$ an inch wide and about $\frac{1}{4}$ inch thick (see Fig. 109). A $\frac{3}{16}$ inch brass rod $2\frac{1}{4}$ inches long, and a $\frac{3}{16}$ inch brass rod $1\frac{1}{8}$ inches long and both of which have their ends threaded (Fig. 110), together with the adjusting nut (Fig. 111) and a pair of binding posts, complete the parts of the detector.

Now take the two large springs and place one of the brass collars between them at one end, slip the short threaded brass rod through them and screw on a nut. Slip the finger with the slot in it on the other end of the rod and screw on the adjusting nut. Put a collar between the springs at the other end and slip the longer threaded brass rod through the holes. Outside of each of the springs and over the rod slip a collar and on the collar next to the spring which carries the finger with the pointed contact set the adjusting screw

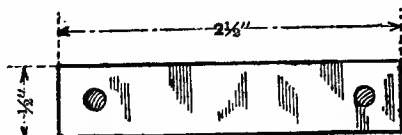


FIG. 109.—BRASS SPRING.

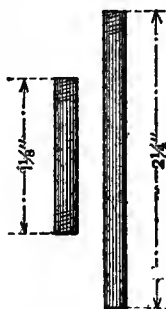


FIG. 110.—BRASS SUPPORT ROD.

arm, put on a washer and screw on a nut. Push the end of the rod through the hole in the base, put a couple of washers on the end of the rod on the bottom side of base and screw on a nut, all of which is clearly shown in the side view of the detector (Fig. 101).

Screw the binding posts to the base in their proper places and connect one of the binding posts with the brass well by means of a piece of insulated wire and the other binding post with the support as shown by the dotted lines in Fig. 101, and the frame of your detector is done. It is shown in its completed form in Fig. 112.

You will see that this detector has three means for adjustment, and these are: (1) The well can be moved from side to side; (2) the contact point can be moved forward and backward and from side to side, and (3) these two movements permit the phosphor-bronze point to be placed in any position on the surface of the crystal in the well, while the adjusting screw gives the needed pressure for bringing the phosphor-bronze point into contact with the crystal.



FIG. 111.—ADJUSTING NUT.

There are many kinds of crystals used in crystal detectors, but the kind known as *fool's gold*, or to call it by its right name, iron sulphid, works about as well as any, but silicon is largely used. But all kinds of iron sulphid will not work as a detector, so when you order be sure to say you want the bright crystalline kind.

The Condenser.—For this receiving set you can use either (1) a *fixed* condenser, or (2) a *variable* condenser. The former is

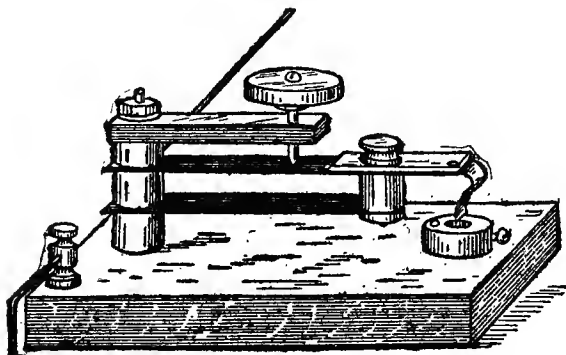


FIG. 112.—CRYSTAL DETECTOR COMPLETE.

very easily made but you will have to do all of your tuning with the tuning coil. The latter is troublesome to make and will probably cost you as much as a ready-made one. The advantage of a variable condenser is that you can tune very sharp with it.

The Fixed Condenser.—To make this condenser get enough tin foil to make five leaves $1\frac{1}{2}$ by 3 inches on the sides; and lay these alternately with the sheets of mica; that is, lay a sheet of mica down first; then lay a sheet of tin foil on top of the mica as shown in *Fig. 113*, with the end of the tin foil lapping over the edge of the mica $\frac{1}{4}$ inch and on the right-hand side. This leaves a margin of mica $\frac{1}{4}$ inch all around on the other three sides.

Another sheet of mica is now laid on the tin foil, and another sheet of tin foil is laid on the mica, this time with the

overlapping end on the left-hand side as shown in *Fig. 114*, and so on until all the sheets of mica have been used. The diagram (*Fig. 114*) shows the sheets of mica and leaves of

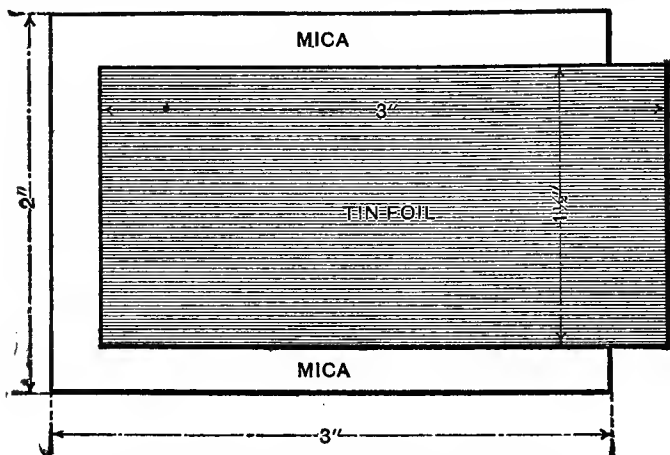


FIG. 113.—TIN FOIL LAID UP WITH MICA.

tin foil separated but, of course, when the condenser is actually laid up the sheets and leaves are close together.

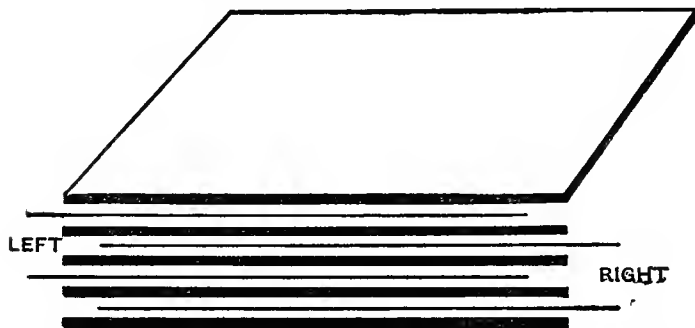


FIG. 114.—DIAGRAM SHOWING HOW MICA AND TIN FOIL ARE LAID UP.

After the condenser is laid up, cut two pieces of stiff paste-board the size of the mica, place one on each side of the con-

denser like the cover of a book, and put a rubber band round each end to hold the mica and tin foil in place.

The next thing is to solder a wire to each end of the con-

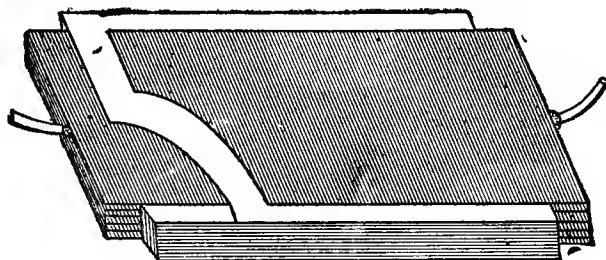


FIG. 115.—CONDENSER WITH SOLDERED ENDS.

denser. To do this place the condenser between a pair of smooth boards and screw it up in a vice with one end of the condenser up and above the boards. Sprinkle a little powdered rosin between the ends of the leaves of tin foil and then with a hot

soldering iron melt some solder and let it fall a drop at a time on the tin foil. Do not touch the tin foil with the hot iron or it will melt away. Soon all the ends of the leaves will be melted in with the solder, and a firm metal edge will result as shown in Fig. 115.

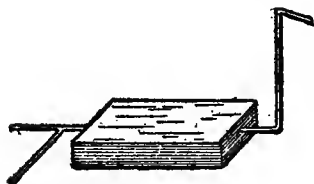


FIG. 116.—CONDENSER COMPLETE.

Now cut off two pieces of insulated wire about 4 inches long and scrape the ends clean. Lay an end of one of these wires on the soldered end of the condenser, sprinkle on a little rosin and hold your soldering iron on it until the solder runs just enough to hold the wire firmly.

Dip the whole condenser in melted paraffin several times until the paraffin has gotten into every crevice and then lay it on a table and put a flat-iron or other weight on it.

Make a little wooden box $2\frac{1}{2}$ inches wide, $3\frac{1}{2}$ inches long and

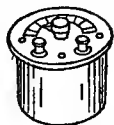
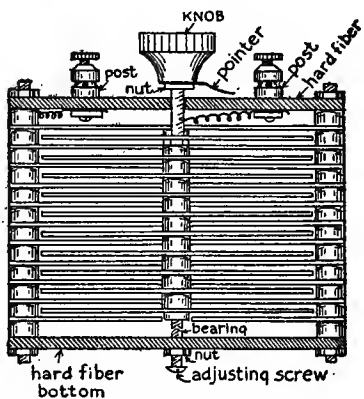
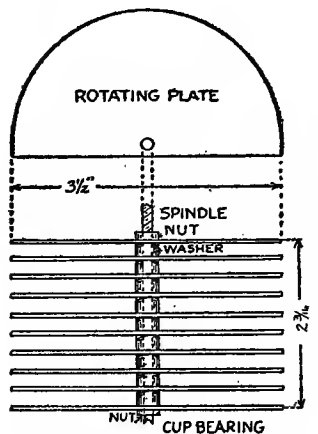
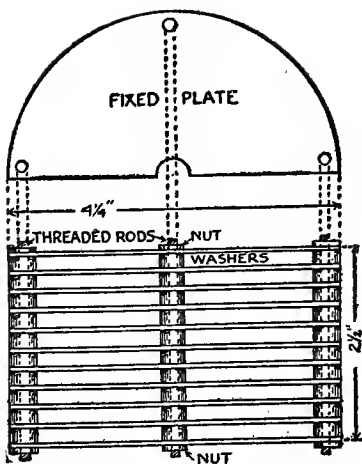
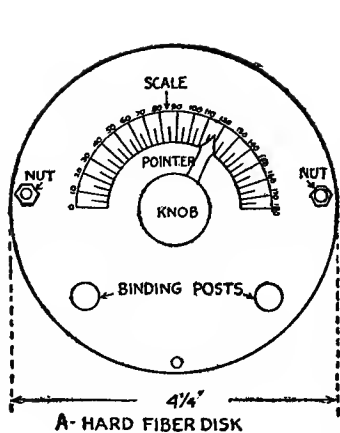


FIG. 117.—HOW THE VARIABLE CONDENSER IS MADE.

$\frac{1}{2}$ inch high on the inside. Drill two holes in the opposite ends of the box and draw the wires through the holes as shown in Fig. 116. Fill the box with melted paraffin and glue on the top.

The Variable Condenser.—This condenser consists of a number of fixed semicircular brass or aluminum plates, and a number of movable semicircular metal plates arranged so that they interleave with each other. By turning the knob the movable plates are moved in or out of the fixed plates and in this way the capacitance of the condenser is varied.

For this condenser you will need the following material: (1) two hard fiber disks with holes drilled in them as shown at *A* in Fig. 115; (2) eleven large semicircular fixed metal plates (see *B*); (3) ten small semicircular movable metal plates (see *C*); (4) four brass rods $\frac{1}{8}$ inch in diameter and $3\frac{5}{8}$ inches long; (5) ten hexagonal nuts; (6) thirty-three washers $\frac{3}{16}$ inch thick, $\frac{3}{8}$ inch in diameter and with a $\frac{1}{8}$ inch hole in them; (7) a knob; (8) a scale; (9) two binding posts, and (10) an $\frac{1}{8}$ inch adjusting screw.

To assemble the condenser, thread the ends of all the rods; hollow out one end of the rod you are going to use for the shaft. Begin by building up the fixed plates and this you do by screwing a nut on each one of the support rods, then placing the hard fiber bottom on it, then a washer on each side, then a plate and so on until you reach the top. Next build up the movable plates in the same way and when you get to the top, screw on a nut on the rod to hold them firmly in place. Now screw the adjusting screw in the bottom hard fiber plate and slip the movable plates between the fixed plates.

Next screw the binding posts to the top hard fiber plate and connect one of the fixed plate supports and one of the posts together and then connect the shaft of the movable plates with the other post. This done set the hard fiber top over the ends of the supports and screw a nut on each one. Finally screw a knob on the shaft and your condenser is done. The cross section *D* shows all the details of assembly. It is better to have a pointer, which you can make out of tin, and a scale which you can mark off on a piece of paper so that you can see just what you are doing. The completed variable condenser is shown at *E*.

The Telephone Receiver.—A telephone receiver used for long distance wireless work is formed of two watch-case receivers connected with an adjustable head band so that it can be easily and quickly fitted to the head. The bands are made of strips of spring brass or steel and are either nickel-plated or covered with hard rubber or leather.

The ends of the head band are usually slotted and are attached to the cases of the receiver by means of a hinged joint, or, better, with a ball and socket joint; this latter kind of a joint gives a greater freedom of movement and allows the ear-piece to be fitted closely to the ear and this helps the operator to hear the faintest sounds.

A telephone receiver to work properly with a crystal detector should have the coils of its magnets wound to a resistance of 1,000 ohms to 2,000 ohms. Usually the higher the resistance of the magnet coils of a telephone receiver the more sensitive it is, but there are other things which go to make a telephone receiver good, bad or indifferent.

With your pair of head telephone receivers you should buy a cord 6 feet long so that you can move freely about when you have them on, as this is a great convenience when you are sending and receiving.

Wireless telephone receivers cost anywhere from \$3.00 to \$12.00 a pair and so you must let your pocketbook be the judge of the price you pay. A pair of head telephone receivers is shown in *Fig. 118*.

The Potentiometer (Pronounced po-ten'-she-om'e-ter).—Potentiometer is a big word and means an apparatus for measuring electric pressures. It is a word which never should have been used for the *variable resistance* of a wireless receiving set, since electric pressures, which are set up by the crystal, are not measured but simply varied to meet the needs of the detector. But since the word is used by all wireless workers, right or wrong, we must accept it and use it too.

There are very few crystals used in wireless which need a battery current to make them work. The reason for this is because the high frequency currents set up in the aerial by the incoming electric waves are changed into direct current and this direct current is usually large enough to work a pair of telephone receivers without using a current from a dry cell.



FIG. 118.—HEAD TELEPHONE RECEIVERS.

A current from a dry cell will, though, sometimes make the signals in the telephone receiver louder than those produced by the current received by the aerial wire and changed into a *direct current* by the detector.

If now a dry cell is used to supply the extra direct current to the detector and telephone receiver a *potentiometer*, or *variable resistance*, should be used so that exactly the right amount of current can be had to make the loudest signals.

A simple and very good potentiometer can be made on exactly the same lines as the *water rheostat* which was described in Part II, Chapter I, on page 62, for the sending apparatus.

Make a piece of wood 5 inches long, $3\frac{1}{2}$ inches wide and $\frac{3}{4}$ inch thick as shown in *Fig. 119*, and drill two holes $\frac{1}{8}$ inch in diameter in the center of the circles which show the positions of the binding posts. On the under side of the band cut out these holes to $\frac{3}{4}$ inch in diameter and, to within $\frac{1}{4}$ inch of the top

as in Fig. 119. When these are done put on a couple of binding posts.

Saw out a support of the same kind of wood and make this $4\frac{1}{2}$ inches long (or high), $3\frac{1}{4}$ inches wide at one end and 1 inch wide at the other end. Screw this support to the end of the base nearest the holes as in Fig. 120.

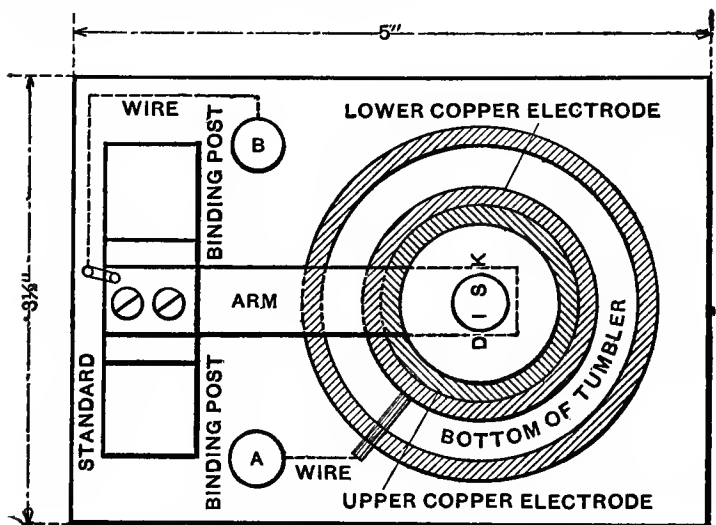


FIG. 119.—TOP VIEW OF WATER POTENTIOMETER.

Now make a brass arm $3\frac{1}{4}$ inches long, $\frac{1}{2}$ inch wide and $\frac{1}{4}$ inch thick and drill two $\frac{1}{8}$ inch holes in one end and ream them out as in Fig. 121 so that the heads of the wood screws will set *in flush* when the arm is screwed down to the support as in Fig. 120. Drill a hole $\frac{1}{8}$ inch in diameter and $\frac{3}{8}$ inch from one end and tap it for the adjusting rod which screws into it.

The adjusting rod is formed of a piece of brass rod $\frac{1}{8}$ inch in diameter and 5 inches long. Cut threads on the rod to about half its length to fit the threaded hole in the arm. On the plain end of the rod screw in or solder on a *disk* of copper or of zinc, $1\frac{1}{2}$ inches in diameter and, say, $\frac{1}{8}$ inch thick (see Fig. 122).

Next screw the rod through the arm and screw on a nut $\frac{5}{8}$ inch from the end, slip on a washer and put on a hard rubber,

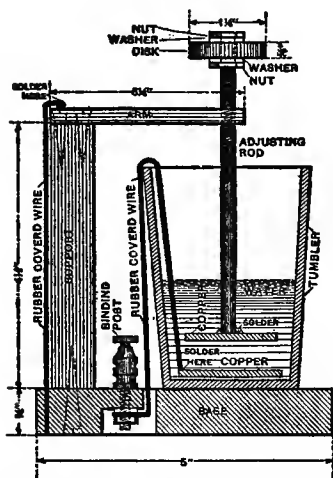


FIG. 120A.—SIDE VIEW OF WATER POTENTIOMETER.

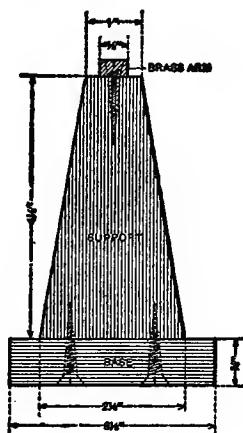


FIG. 120B.—END VIEW OF WATER POTENTIOMETER.



FIG. 121.—BRASS ARM FOR WATER POTENTIOMETER.

or a wood disk, $1\frac{1}{4}$ inches in diameter and $\frac{1}{4}$ inch thick, see *Fig. 123*, and slip on another washer and screw on another nut when the adjusting rod is complete as shown in *Fig. 119*.

Scrape clean the ends of a rubber-covered copper wire 8

inches long and solder one end to the other copper or zinc electrode which should be about $1\frac{3}{4}$ inches in diameter (see Fig. 124) and place this electrode in the bottom of an ordinary glass tum-

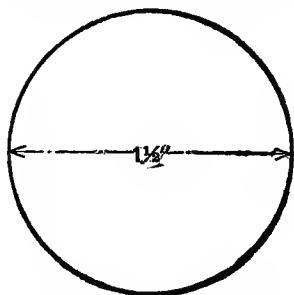


FIG. 122.—UPPER COPPER ELECTRODE.

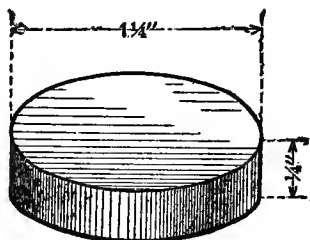


FIG. 123.—ADJUSTING DISK.

bler; bring the wire up the side of the glass, bend it over the top and set the tumbler on the base; now lead the wire through a

hole in the base and connect the free end with one of the binding posts by looping it around the screw and between the washers.

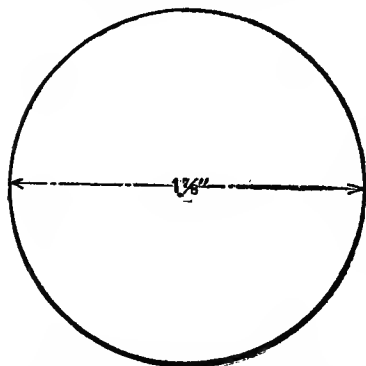


FIG. 124.—LOWER COPPER ELECTRODE.

To the end of the arm on the support solder an end of an insulated copper wire and bring this down back of the support through a hole in the base and over to the screw of the other binding post. Pour about half a glass of water into the tumbler and your potentiometer is ready for use. It is shown complete in Fig. 125.

It is shown complete in Fig. 125.

The Dry Cell.—A dry cell of the ordinary kind, see Fig. 1, page 2, is used in connection with the potentiometer; or a bat-

tery of two or more dry cells can be used by joining them together, but one cell usually gives all the current needed.

The Switch.—The switch for breaking the dry cell circuit when the receiver is not in use is the same as that shown in Fig. 20, page 15, for the small receptor.

Connecting up the Apparatus.—When you have all of the pieces of apparatus for the receptor place them on the operating table on the left-hand side of your transmitter in about the position shown in the plan view, Fig. 126 and screw them down tight.

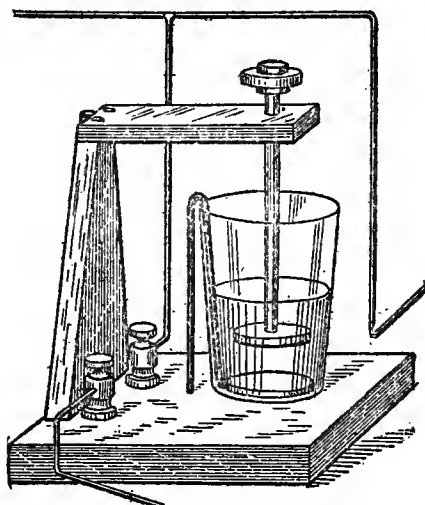


FIG. 125.—WATER POTENTIOMETER COMPLETE.

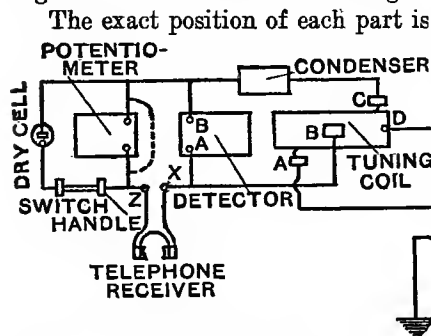


FIG. 126.—PLAN VIEW OF INSTRUMENTS ON TABLE.

The exact position of each part is merely a matter of choice, though the tuning coil and the detector should be close to the key of the transmitter, as the tuning coil will have to be adjusted very often in order to get the incoming signals clear and loud in the receiver.

The detector should be placed close to the tuning coil on the left or you may set it in front of the tuning coil, as this is also a device which will frequently need adjustment.

Screw into the table on the left of the detector a pair of *triple binding posts*, that is the kind of binding post which has three holes and three set screws for connecting in the wires. Three holes in each binding post are needed, as three wires lead to each post, as will be seen presently.

The potentiometer may be placed to the left of the detector with the dry cell to the back, or on the side of it with the switch

in front. After all the parts are set on the operating table just where you want them screw them down tight.

Wiring up the Receptor.—To wire up the various parts follow the wiring diagrams, Figs. 127 and 128. These diagrams are alike except that one has the potentiometer and the other is without it.

In either case begin by connecting the slider A of the tuning coil, by means of the wire attached to one of the rods it slides on, to the ground. Connect the wire of the slider B with the triple binding

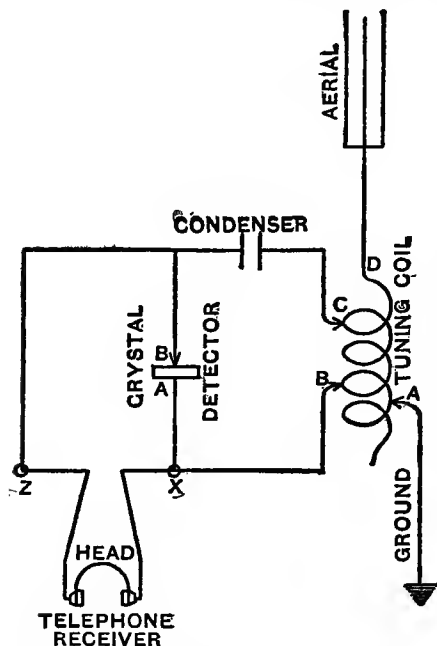


FIG. 127.—WIRING DIAGRAM OF RECEPTION WITH POTENTIOMETER.

post marked X and which is screwed to the table; connect the binding post A of the detector, which leads to the brass well, to the binding post marked X and also connect one end of the telephone receiver cord with the binding post marked X.

From the rod of the slider C run a wire to one end of the

condenser and connect the other end of the condenser with the binding post of the detector marked B and which is connected with the phosphor-bronze point as shown in Fig. 100.

If the detector is to be used without the potentiometer all

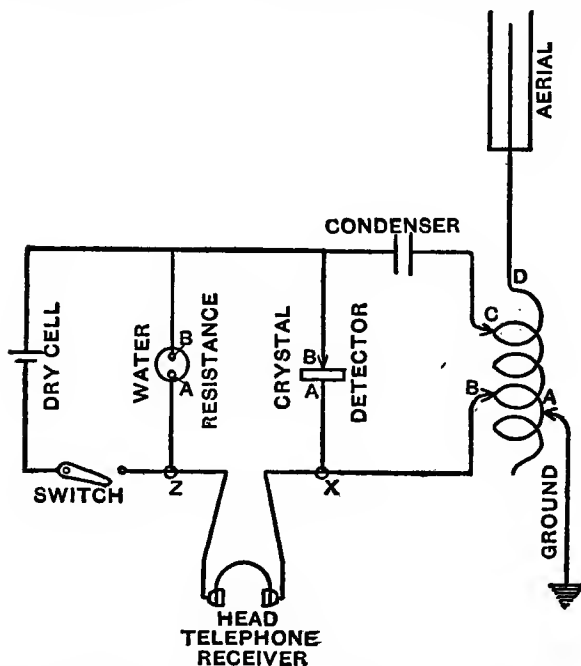


FIG. 128.—WIRING DIAGRAM OF RECEPTOR WITH POTENTIOMETER.

that remains to be done is to connect the binding post B of the detector and the other end of the cord of the telephone receiver with the binding post Z which is screwed to the table; these connections are shown in Fig. 127.

But if the potentiometer is to be used then connect the binding post B of this device with the binding post B of the crystal detector as shown in the wiring diagram, Fig. 128. Connect the binding post marked A of the potentiometer with the binding post Z and also with one end of the switch. Connect the

binding post B of the potentiometer to the carbon of the dry cell and connect the zinc of the dry cell to the switch. The receptor is now ready to be adjusted.

Adjusting the Receptor.—When you adjust the receptor for the first time after wiring it up it is better not to use the potentiometer and dry cell shunted around the detector as shown in Fig. 128, but to connect the telephone receiver directly to the binding posts of the detector as shown in Fig. 127. The receptor complete and ready for use is shown in Fig. 129.

To Adjust the Receptor Without the Potentiometer.—Put on the head telephone receivers and fit the cases closely to your ears. Adjust the detector by screwing the adjusting screw up and down and changing the position of the phosphor-bronze point on the crystal until you hear a slight crackling sound which means that you have found a sensitive point on the crystal.

There are certain parts or spots on crystals that are very sensitive and other places which give no results at all, so the only thing to do is to hunt around and find the best spot. Once you have found a sensitive spot do not move the phosphor-bronze point again, but simply vary the pressure of the phosphor-bronze point on the crystal by means of an adjusting screw, but be careful that you do not use too much pressure.

Now adjust your tuning coil. If there is a wireless station working near you, this will be a fine experience. Set the sliders B and C close together in the middle of the coil and the slider A near the end of the coil opposite the one to which the aerial wire is attached.

Begin to tune by slowly moving the sliders B and C apart and should you hear the faint buzzing of dots and dashes of some station sending messages move the sliders to and fro until you hear the signals the loudest; then move the slider A until you hear the signals still louder.

A very little practice will enable you to adjust the tuning coil so that the signals of any station will ring clear and loud in the receivers, since by moving any one of the sliders one way or

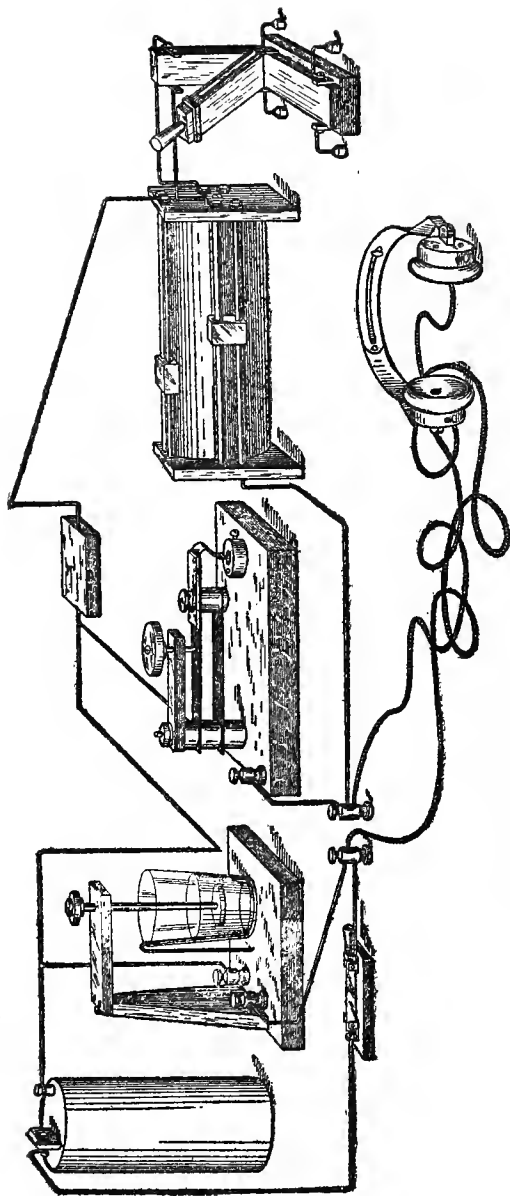


FIG. 129.—RECEPTOR COMPLETE AND READY FOR RECEIVING.

the other over the coil even a trifle, the signals will grow weaker or stronger and hence you know just which way you should move them.

To Adjust the Receptor with the Potentiometer.—After you have learned to adjust the detector and tuning coil so that you can get good results, connect in the potentiometer and dry cell as shown in the wiring diagram, Fig. 128.

Before closing the battery switch have the copper electrode of the adjusting rod as high as it will go; now close the switch and begin to screw down the rod; this will be slow work the first time but once you have found the proper distance between the copper electrodes, and you will know this by the strength of the signals, you will not need to change the adjustment very much.

In connecting in the potentiometer you must be very careful to see that the current from the dry cell flows through the detector in the *same direction as the direct current* made by the detector from the high frequency currents which are set up in the aerial wire by the incoming waves. If the connections are made as shown and described these currents will flow in the same direction.

COST OF RECEPTOR WHEN BOUGHT OF DEALERS ¹

1 tuning coil—3 slides.....	\$3.50
1 crystal detector	5.00
1 pair of standard 1,000 ohms receivers.....	4.00
1 fixed condenser	1.00
1 potentiometer (carbon)	1.50
1 dry cell .....	.20
1 baby knife switch.....	.25
2 triple binding posts.....	.30
	<hr/>
Total	\$15.75

¹The prices of the different parts of the above receptor are only approximate and you should get prices from a number of dealers before buying.

COST OF RECEPTOR WHEN HOME-MADE

Tuning Coil

1 core of wood (turned).....	\$.20
2 wood cheeks.....	.10
6 feet $\frac{1}{4}$ -inch brass rod or tubing.....	.50
6 hexagon nuts .....	.10
1 piece of brass rod for sliders.....	.30
1 phosphor-bronze spring .....	.10
1 pound, enameled wire.....	1.50
4 binding posts .....	.40

 \$3.20
The Crystal Detector

1 wood base	\$.10
All brass needed except binding posts.....	.50
1 oz. silicon crystals.....	.25
Rubber handle for adj. screw.....	.15
2 binding posts .....	.20
Screws and nuts.....	.10

 Total \$1.30

Telephone Receiver (1,000 ohms)..... \$4.00
The Condenser

15 sheets of mica—2 x 3 inches.....	\$.35
Tin foil .....	.10
Box .....	.10

 \$.55
The Potentiometer

Wood for base and standard.....	\$.20
Brass for adjusting rod and arm.....	.25
Copper or zinc electrodes.....	.10
Binding posts .....	.20
Tumbler (glass) .....	.05

 .80

Baby knife switch.....	.10
2 triple binding posts.....	.30

 Total cost to make receptor.....\$10.25

CHAPTER III

A GOOD 'AËRIAL WIRE SYSTEM

With a well made transmitter and receptor you should by all means have a good *aërial wire system*. The term *aërial wire*

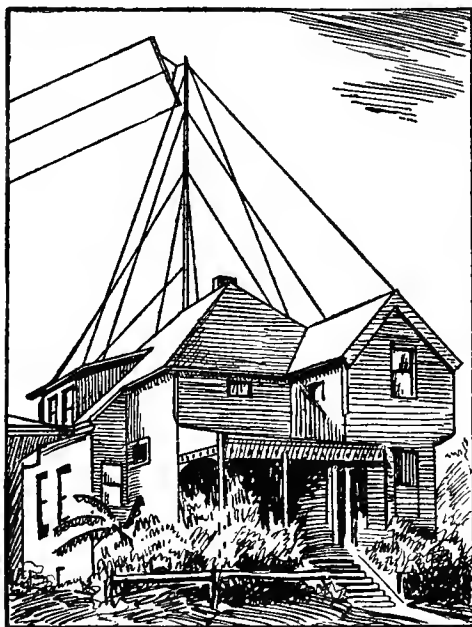


FIG. 130.—MAST—ON TOP OF THE HOUSE.

system means the aërial wire, the ground and that part of the tuning coil which is connected with them.

To be able to send and receive messages over the longest possible distance the aërial wire must be highly insulated to prevent the high-pressure currents used in sending and the feeble currents set up by the incoming electric waves in receiving from leaking away.

As all the material used in an aërial can be bought at a hardware store, to make and put up a good aërial is a simple matter. To get a place where the stretch is long enough and where there are two points high enough for your aërial is the hardest part and in

this you will probably have a chance to show your ingenuity. No hard and fast rules can be given for this part of the work, as conditions everywhere are different.

The best way to get a suitable height is to put up a pole 30 or 40 feet high on top of your house as shown in Fig. 130, making the total height from the ground something like 60 or 70 feet. Of course a pole or mast need not be used and many boys are doing good work with low aërials, as the one described in Part I, Chapter III, but the higher the aërial the longer distance you will be able to send and receive over.

The Horizontal, or Flat-Top, Aërial.—There are many kinds of aërials (see Appendix E) but as all ships and nearly all shore stations have what is called the *horizontal*, or *flat-top* aërial—different names for the same kind of an aërial—this is the kind you should make and put up if conditions will permit.

This kind of an aërial, which is shown in Fig. 27, Part I, Chapter III, is made up of two or more parallel wires and is supported between two points of about equal height, like the masts of a ship.

While a high and a long aërial gives the best results so, too, a large number of wires adds to its sending and receiving power, that is if the wires are not too close together. The wires of an aërial should be at least 2 feet apart and so it will be seen that not more than three or four wires can be used to advantage as a 7-foot spreader is about as long as it is safe to put up in most places.

The aërial should have a stretch of at least 100 feet if a $\frac{1}{2}$ kilowatt transformer is used for sending, and if you cannot get as long a stretch for your aërial as this then a smaller transformer, say $\frac{1}{4}$ kilowatt, will give just about as good service and will be much cheaper.

Making an Aërial.—The materials needed to make a good three-wire aërial, which let us suppose is to be 150 feet long, are:

550 feet of aluminum or bronze wire.

2 spruce spreaders $2\frac{1}{2}$ inches in diameter and 5 feet long.

8 No. 6 electrose ball insulators.

- 1 spruce spreader $1\frac{1}{2}$ inches in diameter and 5 feet long.
- 1 spruce spreader 1 inch in diameter and 2 feet long.
- 6 galvanized iron withes $2\frac{1}{2}$ inches in diameter and having two eyes.
- 6 galvanized iron S hooks, $2\frac{1}{2}$ inches long.
- 2 thimbles, for $\frac{1}{4}$ inch wire rope.
- 2 thimbles for $\frac{3}{4}$ inch manilla rope.
- 6 brass stops, $\frac{1}{2}$ inch long and $\frac{1}{2}$ inch in diameter.
- 6 porcelain insulator tubes, $\frac{1}{2}$ inch in diameter and 3 inches long.
- 2 tackle blocks, of iron or wood, and
Enough manilla rope, $\frac{3}{4}$ inch in diameter.

Kinds of Wire.—There are four kinds of wire which may be used for the aerial and these are: (1) galvanized iron wire; (2) aluminum wire, (3) phosphor-bronze wire, and (4) silicon-bronze wire.

(1) Galvanized iron wire is not as good as the others for the reason that iron is not a good conductor of electricity; the good thing about galvanized iron wire though is that it is cheap.

(2) Aluminum wire is almost as good a conductor of electricity as copper; it is very light, quite strong and is a little cheaper than copper wire. If you use aluminum wire get No. 12 size Brown and Sharpe gauge, which is about $\frac{1}{8}$ inch in diameter.

(3) Phosphor-bronze wire is an alloy made of copper and tin with a small amount of phosphorus in it. It is almost as good a conductor of electricity as copper; it is as tough as wrought iron and does not corrode easily. For this reason it is largely used for aërials. Get it soft drawn and made up of seven strands, each of which is No. 22 Brown and Sharpe gauge.

(4) Silicon-bronze wire is much cheaper than phosphor-bronze and is almost as strong.

Stranded wire is better for aërials than solid wire, as it has a larger surface, and this makes it a better conductor of high-frequency currents. Soft-drawn wire is much easier to handle

than hard-drawn wire and this should not be overlooked when ordering.

The Spreaders.—Any kind of strong sticks will, of course, do for the *spreaders*, but it gives a fellow a lot of pleasure to have a good-looking aerial as well as a good working one.

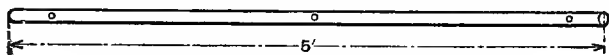


FIG. 131.—THE SPREADER FOR THE ENDS.

Four spreaders are needed, one at each end of the aerial, one in the middle to keep the wires apart, and a short one for the *leading-in* wires. Make these spreaders of *spruce* if you can get this kind of wood, for spruce is light, springy and strong. If you cannot get spruce use hickory, though hickory is heavier than spruce.

Make the two end spreaders 5 feet long and 2 inches scant in diameter, as shown in Fig. 131; make the middle spreader 5 feet long and $1\frac{1}{2}$ inches in diameter, as in Fig. 132, and the leading-in spreader 2 feet long and 1 inch in diameter, as shown

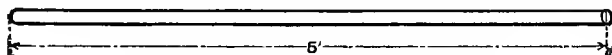


FIG. 132.—THE MIDDLE SPREADER.

in Fig. 133. Drill three $\frac{1}{8}$ inch holes in the middle spreader (Fig. 132) and the leading-in spreader (Fig. 133)—a hole in the middle of each spreader and a hole at each end—so that the wires can be slipped through them.

The Spreader Withes.—Withes are simply galvanized iron rings with eyes attached to them. Six of these withes are needed—three for each of the end spreaders. Each withe should have two *eyes* as shown in Fig. 134 and have an inside diameter of $2\frac{1}{2}$ inches.

Slip three withes on each of the end spreaders—one for the middle and the other two for the ends. Drill a hole through each withe and drive in a screw to keep it from slipping on the spreader.

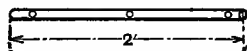


FIG. 133.—LEADING-IN SPREADER.

The Ball Insulators.—To properly insulate the wires from the masts is most important and you will never have a good station unless this is done.

SIDE VIEW



END VIEW

FIG. 134.—WITHE WITH TWO EYES.

The insulators generally used for high-grade aërials are made of a patented compound and are called *electrose insulators*. Electrose is almost as good an insulator as hard rubber, while it is very much stronger, is not affected by heat or cold, is waterproof, and, finally, it is cheaper than hard rubber.

The ball insulators made of electrose and which are used for holding the wires to the spreaders and the spreaders to the masts have eyes fastened to them as shown in Fig. 135. Eight No. 6 ball insulators will be needed—four at each end of the aërial.



FIG. 135.—ELECTROSE BALL INSULATOR.

Other Hardware Needed.—To complete the list of materials for your aërial buy six galvanized iron S hooks, $2\frac{1}{2}$ inches long, as shown in Fig. 136, and connect the ball insulators with the rings of the withes on the end spreaders as shown in Fig. 137.

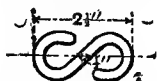


FIG. 136.—S HOOK.

Next make, or have made, six brass stops, each of which is formed of a piece of brass rod $\frac{3}{8}$ inch in diameter, $\frac{1}{2}$ inch long and having a $\frac{1}{8}$ inch hole drilled through it so that it will slide on the wire; also drill a hole, tap it and fit in a

short machine screw so that the stop can be screwed tight to the wire when it is put in position. One of these stops is shown in Fig. 138. A pair of the stops are put on the opposite sides of the middle spreader to prevent it from slipping out of place on the wires.



FIG. 137.—S HOOK LINKING BALL INSULATOR WITH WITHE.

Steel Wire.—Get 20 feet of stranded steel wire $\frac{3}{8}$ inch in diameter—10 feet for each end of the aërial. Stranded steel wire is used at the ends of the aërials instead of manilla rope, as it does not stretch in wet weather. Cut the wire into four lengths and have two pieces 7 feet long and two pieces 3 feet long.

Thimbles.—Thimbles are galvanized iron ovals with grooves formed in them (see Fig. 139) and around which the steel wire or manilla rope is looped and fastened. Four thimbles will be needed, a large one and a small one at each end of the aerial. The small thimbles have $\frac{1}{4}$ inch



FIG. 139.—THIMBLE.

grooves in them so that the stranded steel wire will lay in snugly, while the large ones have $\frac{3}{4}$ inch grooves to fit the manilla rope.

Shackle Bolts.—Shackle bolts are $\frac{3}{8}$ inch iron rods bent in the shape of the letter U and having eyes formed on the end of the rods so that bolts can be passed through them as shown in Fig. 140. These bolts are used to link the eyes of the insulators at the ends of the aërials with the thimbles holding the manilla rope.

The block is secured to the masthead and by running a manilla rope, one end of which is fastened to the aerial, through the block and over the pulley, the aerial can be hoisted to the top of the mast and lowered if needs be.



FIG. 138.—BRASS SPREADER STOP.

Tackle Blocks.—A tackle block consists of a grooved pulley on an axle and fitted in a case of iron, brass or wood having a ring at one end as shown in Fig. 141.

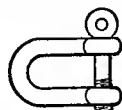


FIG. 140.—SHACKLE BOLT.

The block is secured to the masthead and by running a manilla rope, one end of which is fastened to the aerial, through the block and over the pulley, the aerial can be hoisted to the top of the mast and lowered if needs be.



FIG. 141.—TACKLE BLOCK.

The Manilla Rope.—The amount of rope, which should be $\frac{3}{4}$ inch in diameter, is like the amount of aerial wire, subject to conditions, but you can easily figure out the amount after you have found the height and length of your aerial. Cut the rope into two pieces of the lengths needed and you are ready to assemble the aerial.

Assembling the Aerial.—Begin the work by linking a small thimble—it is open at the sharp end—through the eye of one of the insulators. Now loop the middle of one of the 7 foot

lengths of steel wire around the thimble, twisting the end of one of the 3 foot lengths of steel wire around the other wires at the sharp end of the thimble, and wrap the three wires very tightly with some thin, strong steel wire as shown in Fig. 142.

Bring the free ends of the wires through the eyes in the withes on the end spreader and twist them around themselves

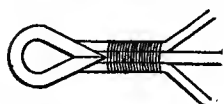


FIG. 142.—JOINING THE STEEL WIRE.

so that there is no danger of their pulling apart. Fix the other steel wires on the thimble and fasten to the remaining end spreader in the same way.

Next loop one end of a piece of manilla rope around one of the large thimbles and splice it to the body of the rope, if you know how to splice well. If not, lay the end close to the body of the rope and wrap it with two or three layers of fish line which must be put on very tightly. The thimble on the end of the manilla rope is linked into the eye of the ball insulator by means of a shackle bolt.

To each of the opposite eyes of the withes on the end spreaders secure a ball insulator with an S hook. This completes both supports of the aerial as in Fig. 143.

Now cut off three pieces of the aluminum or bronze wire each 150 feet long and lay them parallel on the ground. Slip the ends of the wires through the holes in the middle spreader and draw the wires through until the spreader is halfway between. On the wires at each end slip the brass stops and slide these along until they touch the middle spreader. By screwing them to the wires the spreader cannot slip from its position, as will be seen from the detailed drawing, Fig. 144.

Place the finished supports of the aerial close to the ends of the aerial wires, and loop the end of each wire through the eye of an insulator and twist it up tight.

This done, cut off a piece of the aluminum or bronze wire long enough to reach from the top of the mast to your apparatus on the operating table. Twist one end of the leading-in wire to the middle aerial wire and at a point far enough away from

the end spreader so that when the aërial is hoisted to the mast-head the leading-in wire will swing clear of the building.

To each of the two outside aërial wires twist an end of a 10 foot length of wire. Slip the free end of the leading-in wire through the middle hole in the leading-in spreader and slide it

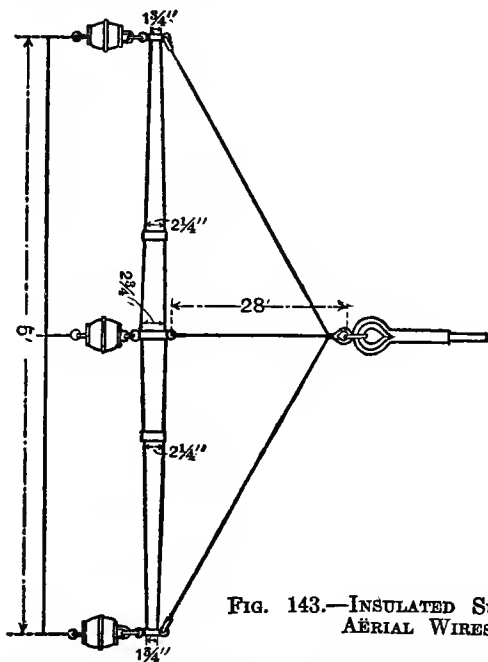


FIG. 143.—INSULATED SUPPORT FOR AËRIAL WIRES.

along until the ends of the shorter wires are reached. Thread these through the holes of the leading-in spreader and twist the free ends around the leading-in wire. The aërial is now ready to be hoisted to the mastheads.

Putting Up the Aërial.—The tackle blocks should be lashed to the mastheads with rope, and ropes long enough so that both ends will reach to the ground when the pole is up should be run through the blocks. All this, though, should be done before the poles are put up on top of the building.

After the poles are set up and guyed out bind one end of the small rope to the free end of the aerial rope and draw it up and through the pulley block. Keep on pulling the rope until the aerial swings high and taut between the mastheads.

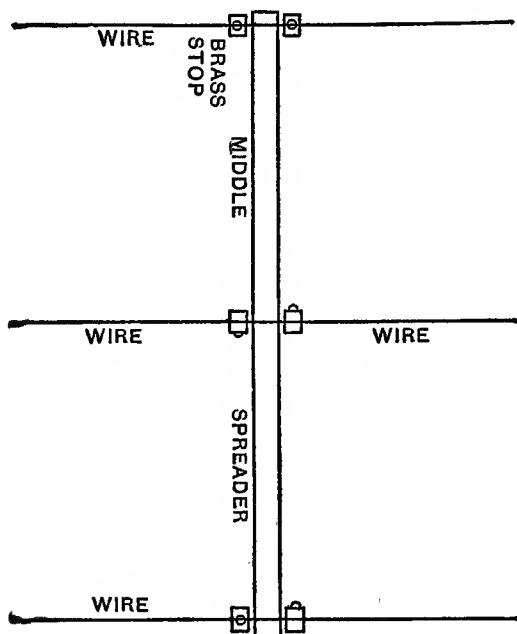


FIG. 144.—BRASS STOPS ON AERIAL WIRE.

The Leading-in Insulator.—With an aerial as well made as the one just described you should keep up the good work and bring the leading-in wire of the aerial through the window-pane if possible.

The best way to do this is to get an electrose *leading-in insulator* which is largely used by the big wireless companies. This leading-in insulator is $5\frac{1}{2}$ inches long, $1\frac{3}{4}$ inches in diameter at its large end and 1 inch in diameter at its shank. The shank, which is $\frac{3}{4}$ inch long, is threaded and a brass ring $1\frac{3}{4}$ inches in

diameter and $\frac{1}{4}$ inch thick is threaded on the inside so that it can be screwed on to the shank as shown in Fig. 145.

Cut a hole $1\frac{3}{8}$ inches in diameter in a window-pane nearest your leading-in wire and put the insulator through the hole with the shoulder of the insulator up against the glass; now screw the threaded brass ring on to the shank on the other side of the pane of glass. Thread the end of your leading-in wire through the hole of the insulator, draw it inside the room and connect it with one side of the aerial switch. The way in which the end of the wire is led through the leading-in insulator is shown in Fig. 146.

The Lightning Switch.—To protect the sending and receiving apparatus from lightning, a lightning switch should be used and in some places the Fire Underwriters require them.

The switch is simply a *double-throw, single-pole knife switch* as shown in Figs. 147 and 148. It is placed on the outside of the building close to the leading-in insulator.

A knife switch of this type mounted on a porcelain base can be bought about as cheaply as one can be made; however, if you want to make the switch yourself get a piece of slate or marble for the base about 3 inches wide, 10 inches long and $\frac{3}{4}$ inch thick. Drill twelve holes $\frac{1}{8}$ inch in diameter in the base for the screws as shown in Figs. 147 and 148.

Now cut from a sheet of brass $\frac{1}{16}$ inch thick six pieces 1 inch long and $1\frac{1}{4}$ inches wide and bend these over in a vise so that an angle plate is formed as shown in Fig. 149. Drill two $\frac{1}{8}$ inch holes through the base of each of these angle plates so that they can be screwed to the slate, or marble base. In two of these angle plates drill $\frac{1}{8}$ inch holes through the part marked contact to form a hinge for the contact blade. Screw all of these angle plates to the slate, or marble base.

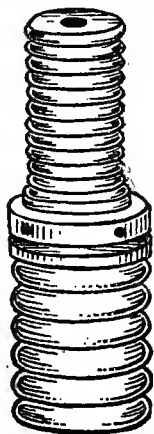


FIG. 145. — LEADING-IN INSULATOR.

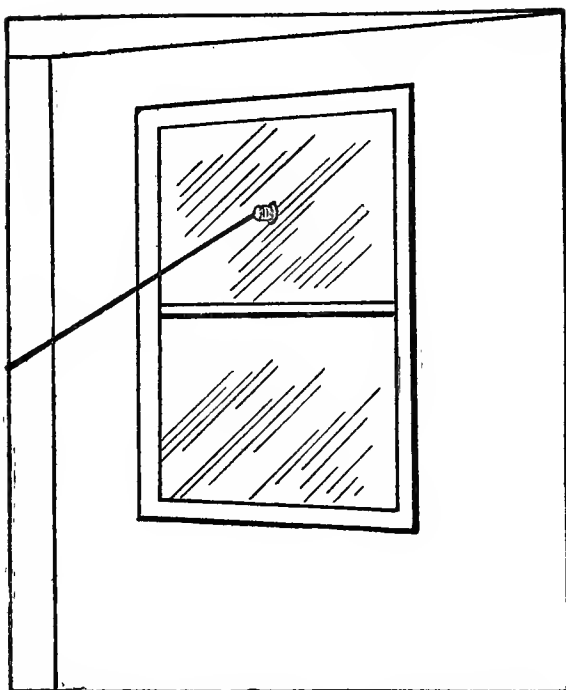
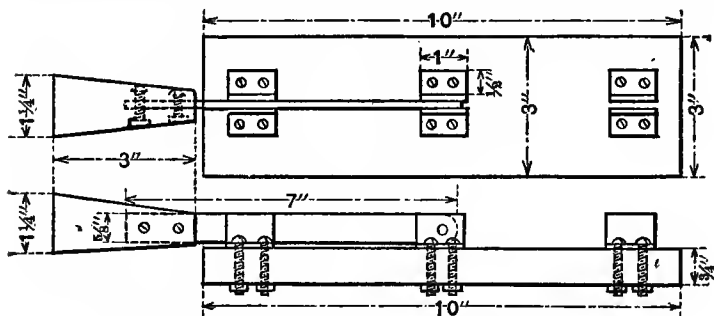


FIG. 146.—LEADING-IN INSULATOR THROUGH WINDOW.

Next make a contact blade of a strip of brass 7 inches long, $\frac{1}{8}$ inch wide and $\frac{1}{8}$ inch thick. Drill a hole $\frac{1}{8}$ inch in diameter,



FIGS. 147 and 148.—TOP AND SIDE VIEWS OF LIGHTING SWITCH.

$\frac{3}{8}$ inch from each end and a third hole 1 inch from one of the ends.

Turn a handle of hard wood 3 inches long and make it 1 inch in diameter at one end and taper it down to $\frac{5}{8}$ inch at the other end and saw a slot in the small end $1\frac{1}{2}$ inches deep. Place the end of the contact blade with the two holes in it in the slotted handle and drill two holes through the wood exactly in a line with the holes in the blade. This done put in a couple of screws to hold it tight. This is clearly shown in Figs. 147 and 148.

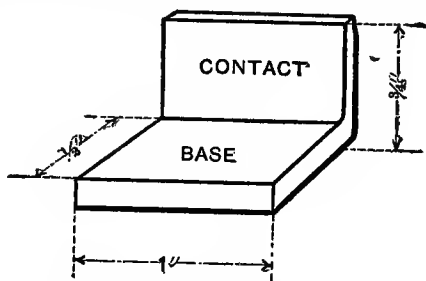


FIG. 149.—ANGLE CONTACT PLATE.

Put the other end of the blade between the middle angle plates, put a screw through the holes, slip on a washer and screw on a nut and your lightning switch is finished.

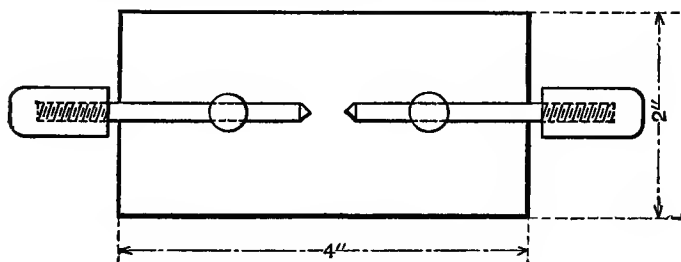


FIG. 150.—A TOP VIEW OF ANCHOR-GAP.

The lightning switch is fastened to the outside of the house with long screws passing through the base and porcelain insulators.

The Anchor-Gap.—An anchor-gap is merely a very small spark-gap and is used to connect one of the ends of the sending

tuning coil with the aërial when messages are being sent and to cut off the sending tuning coil from the aërial when messages are being received.

The purpose of an anchor-gap is to prevent the high-frequency currents set up by the incoming electric waves from flowing into the transmitter and being wasted there in doing useless work.

To make a simple anchor-gap get a base of slate or marble, or of very dry, hard wood, 4 inches long, 2 inches wide, and $\frac{1}{2}$ or $\frac{3}{4}$ inch thick, as shown in Fig. 150. On inch from each end and in the middle of the base drill a $\frac{1}{8}$ inch hole. Drill

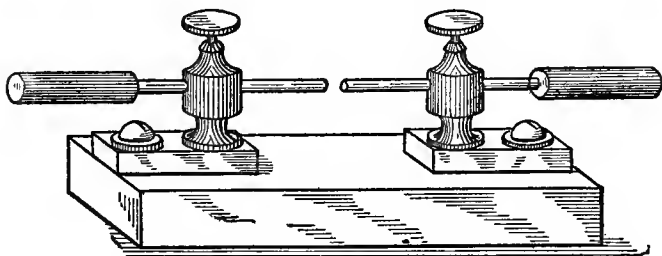


FIG. 151.—ANCHOR-GAP COMPLETE.

these holes out to $\frac{1}{2}$ inch in diameter on the bottom of the base and $\frac{1}{4}$ inch through. Mount two double binding posts on the base as shown in the cuts.

Take two brass rods $\frac{5}{32}$ inch in diameter and thread one end of each one and sharpen the other end. On the threaded ends of the rods screw two handles of wood, or hard rubber, $\frac{1}{2}$ inch in diameter and 1 inch long. It is shown complete in Fig. 151.

The anchor-gap is screwed to the wall and the leading-in wire of the aërial is connected with one of the binding posts. The other binding post of the anchor-gap leads to one of the clips of the tuning coil of the transmitter, all of which is clearly shown in Fig. 88.

The Aërial Switch.—An up-to-date aërial switch which is so arranged that the transmitter cannot be operated when the

receptor is connected to the aerial, thus preventing burn-outs, is the next and last piece of apparatus needed for this set.

All of the woodwork of the aerial switch should be made of thoroughly seasoned hard wood, though the base may be made of pine or some other kind of soft wood. Make the base $9\frac{1}{2}$ inches long, 5 inches wide and 1 inch thick. On top of the base screw a strip of wood $8\frac{1}{2}$ inches long, 2 inches wide and $\frac{1}{2}$ inch

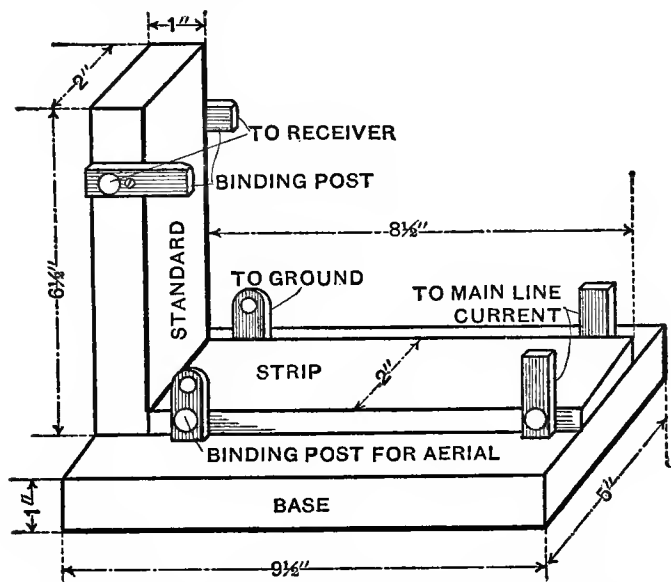


FIG. 152.—BASE AND CONTACT SUPPORTS FOR AËRIAL SWITCH.

thick and screw a standard of wood $6\frac{1}{2}$ inches high, 2 inches wide and 1 inch thick at the end of the base as shown in Fig. 152.

Cut out two contact springs from a sheet of brass about $\frac{1}{8}$ inch thick and make these springs 2 inches long and $\frac{1}{2}$ inch wide and bend out the ends a little, as shown in Fig. 152, to make a good contact. Screw these springs to the opposite sides of the wood standard, $\frac{1}{2}$ inch from the upper end, with wood

screw binding posts and to keep them from dropping down put a small wood screw in each side.

Now cut out two more contact springs $\frac{3}{4}$ inch long and $\frac{1}{2}$ inch wide, bend out the ends of these as you did the others and screw them to the strip of wood $\frac{3}{4}$ inch from the front end with wood screw binding posts as shown in Fig. 152. Cut out two brass plates for hinging the lever and make these $\frac{3}{4}$ inch long and

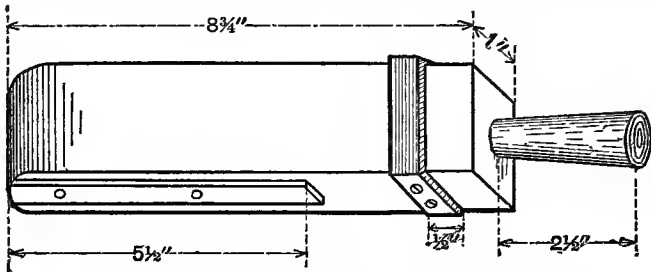


FIG. 153.—CONTACT LEVER FOR AERIAL SWITCH.

$\frac{5}{8}$ inch wide, round off the edges at one end and drill a $\frac{1}{8}$ inch hole through the ends that are rounded off. Drill holes in the other ends and screw these hinge plates to the strip of wood $\frac{3}{4}$ inch from the end which is nearest the standard with a pair of wood screw binding posts.

Make a lever of hard wood $8\frac{3}{4}$ inches long, 2 inches wide and 1 inch thick. Round off one of the ends as shown in Fig. 153 and have a $\frac{1}{2}$ inch hole $\frac{3}{4}$ inch deep in the other end. Have a wood handle turned $3\frac{1}{4}$ inches long, 1 inch in diameter at one end and tapering down to $\frac{1}{2}$ inch in diameter, $\frac{3}{4}$ inch from the other end, the rest of the way down being $\frac{1}{2}$ inch in diameter. Smear the small end of the handle with glue and force it into the hole in the end of the lever.

Screw a strip of brass $\frac{1}{2}$ inch wide to the lever one inch from the top and around it on three sides as in Fig. 153; this is to make contact with the front springs on the strip of wood. Cut two strips of brass $5\frac{1}{2}$ inches long and $\frac{1}{2}$ inch wide and drill three $\frac{1}{16}$ inch holes in each strip—two holes $\frac{3}{4}$ inch from the

Since one of the hinged plates is connected with the ground and the other one with the aërial when the lever is thrown to the vertical position—that is, up—and the brass strips make contact with the upper springs, the aërial and ground wires are connected with the receptor. On the other hand when the lever

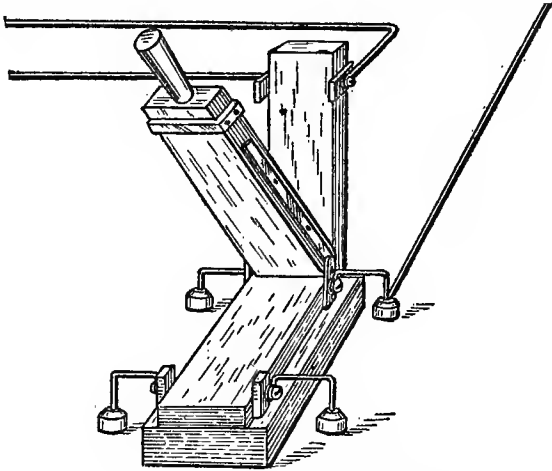


FIG. 155.—AËRIAL SWITCH COMPLETE.

is thrown to the horizontal position—that is, down—the strip of brass around the top of the lever will make contact with the springs on the wood strip and this will close the power circuit which supplies current to the transformer as the plan view, Fig. 86 and Fig. 87, shows. Fig. 155 shows the aërial switch complete.

A Good Ground.—A good ground is just as important a part of a wireless station as a good aërial.

When we speak of the *ground* in wireless we mean the place where the aërial wire system is connected with the earth. A good ground is one where there is little or no resistance between the earth and the wire which connects with it, and hence, the high-frequency currents can flow freely into and out of the earth.

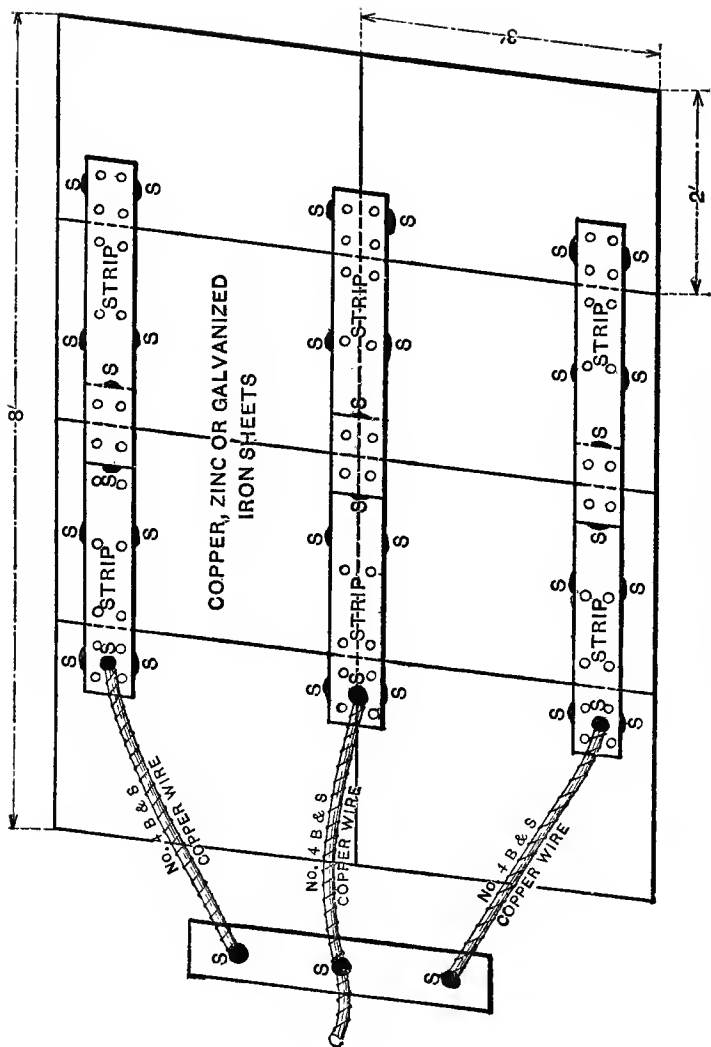


FIG. 156.—THE METAL GROUND.

To obtain a ground in the city the easiest and therefore the usual way is to connect the ground wire with the water or gas pipes, or both, but a better ground may be had by burying several large sheets of metal deep in the damp earth.

Any kind of metal in sheet form will do for a ground, as zinc, copper or galvanized iron. Zinc and copper make the best grounds because they are good conductors of electricity, but galvanized iron works very well and is very much cheaper. For the set I have described the ground should have at least 50 square feet of metal in it and if you can increase this to 100 feet so much the better.

To make a ground take ten sheets of zinc, copper or galvanized iron say 2 feet wide and 3 feet long. Cut two of these metal sheets lengthwise, into strips, 6 inches wide. Lay the remaining eight metal sheets flat on the floor with their edges together and lay six of the metal strips on top of them as shown in Fig. 156.

Now drill twelve holes through each of the pairs of metal strips and the metal sheets and rivet the strips to the metal sheets so that all the metal sheets are joined together. Next solder the metal strips to the metal sheets on the edges where the letter S is marked in Fig. 156 and then solder the ends of three pieces of bare copper wire No. 4 Brown and Sharpe gauge to the strips on the sheets and solder the other ends to a metal strip 3 feet long.

From this metal strip run a No. 4 copper wire, Brown and Sharpe gauge, to your operating table where it is connected with the aerial switch. This wire does not need to be insulated but can be fastened to the side of the house with double-pointed tacks, cleats or in any way that is the easiest.

Putting Down the Ground.—Dig a trench 3 feet wide, 9 feet long and 8 feet deep in soil that is as moist as possible. Fill the hole with water. Let the metal sheets down carefully until the lower edge rests on the bottom of the trench.

Fill in the hole with earth and see that the metal sheets are kept in the middle of the trench; this is done by throwing a

shovelful of earth first on one side and then on the other of the metal sheets. Run water on top of the ground as often as you can and you will have what is called in wireless language a *good ground*.

Connecting the Transmitter and Receptor with the Aërial and Ground.—Having all the apparatus finished and set in place on your operating table and having the aërial wire put up and the ground plate put down, everything is ready for making the final connections.

Place the aërial switch between the transmitter and the receptor, as shown in the plan view, Fig. 157, and set it near the front of the table as it will be constantly in use changing the aërial from the transmitter over to the receptor and back again. Screw the base of the switch to the table so that it cannot move. The anchor-gap should be screwed to the wall where it can be seen and yet where it will be out of the way.

The plan view, Fig. 157, not only shows how the instruments are placed on the operating table but it shows how they are connected up by means of the binding posts. The wiring diagram, Fig. 158, shows the actual connections of all the wires so that you can follow the current from the time it is taken off the power circuit until it reaches the aërial wire system, and from the time it is received by the aërial wire system until it is changed into sound waves in the head telephone receiver. The heavy black lines show the power circuit and the light lines show the high-pressure and high-frequency circuits.

Now connect the end of the leading-in wire of the aërial with the hinged support of the aërial switch marked A. Connect the end of the ground wire with the other hinged support of the aërial switch marked B. To the hinge A, or at some part of the leading-in wire of the aërial before it reaches the leading-in insulator, solder on a piece of wire and lead it to one side of the anchor-gap, and connect the other side of the anchor-gap with the clip A of the sending tuning coil.

Connect the binding post D of the sending tuning coil with the hinge B of the aërial switch, or with some part of the ground

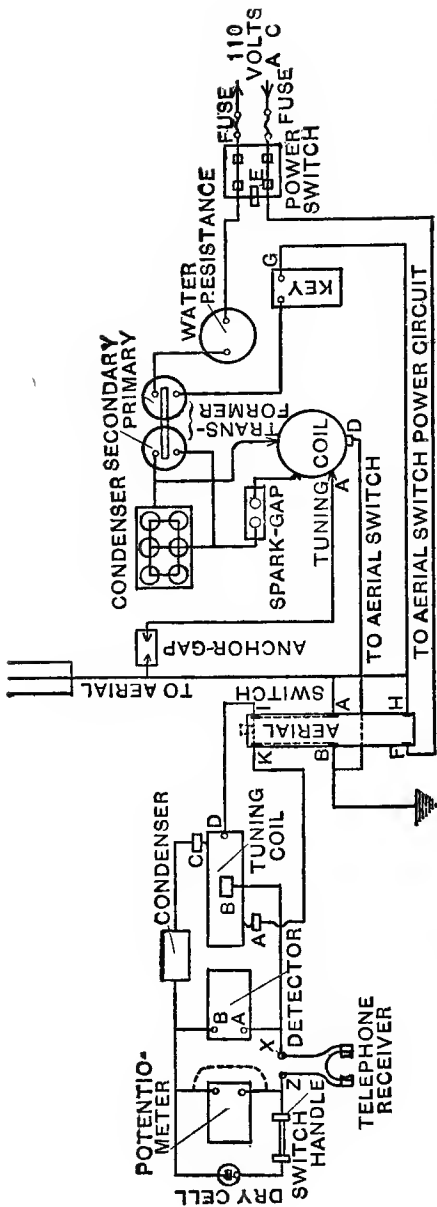


FIG. 157.—A PLAN VIEW OF TRANSMITTER, RECEPTOR AND AERIAL SWITCH CONNECTED TOGETHER.

wire before it passes through the window-sill to the outside as shown in Figs. 157 and 158. Next connect the contact spring E of the power circuit switch with the contact spring F of the aërial switch and connect the binding post G of the key to the contact spring H of the aërial switch.

The binding post D of the receiving tuning coil is connected with the contact spring I of the aërial switch and the slider A of the receiving tuning coil is connected with the contact spring K of the aërial switch. When all these connections are made the apparatus is ready for sending and receiving messages.

Operation of the Sending and Receiving Apparatus.—

We will begin by supposing you are going to send a message. First throw the lever of the aërial switch down when the brass band on top of the lever will make contact with the springs F and H of the power circuit, in which the primary of the transformer and the key are placed. Of course if the key is not closed the circuit will still be open, but the circuit is otherwise closed by the aërial switch and the power switch.

Now when the key is operated, the transformer changes the low-pressure current of the power circuit into high-pressure alternating currents which charge the Leyden jar condenser. When the condenser is charged it discharges through the spark-gap and this sets up high-frequency currents in the tuned closed circuit formed by the condenser, the tuning coil and the spark-gap. These high-frequency currents surge up the wire at A of the tuning coil, through the anchor-gap and to the aërial and back again through the anchor-gap and tuning coil to D and thence to the ground, which together forms a *tuned open circuit*.

Suppose, now, you have sent your message and you want to *listen-in*. Throw the lever of the aërial switch up into contact with the contact springs I and K. When this is done you will see from the plan view, Fig. 157, and the wiring diagram, Fig. 158, that the power circuit is broken at the contact springs F and H; hence even if you forget and try to send a message and begin working the key when *listening-in* no harm will come of it.

The purpose, then, of having the aërial switch break the

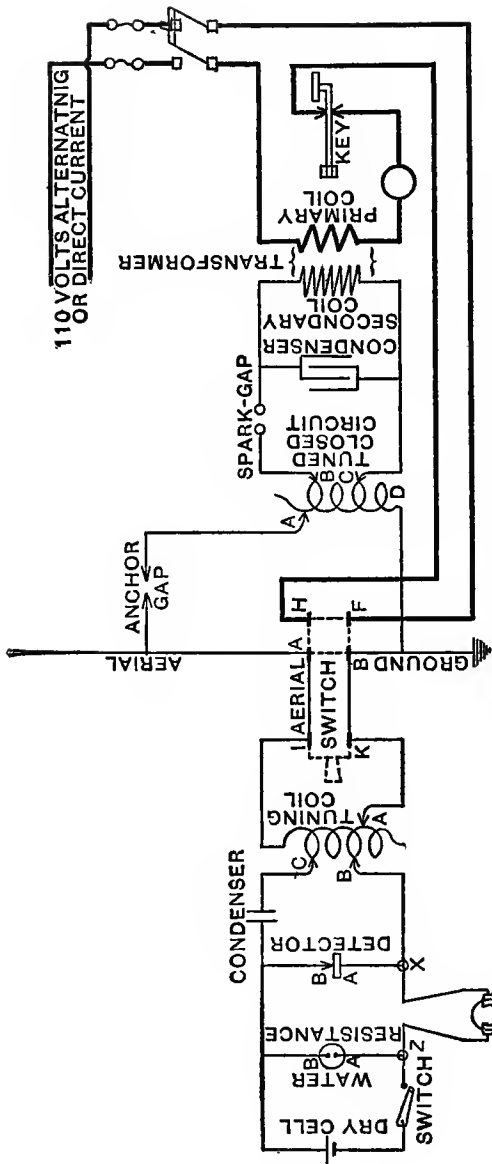


FIG. 158.—WIRING DIAGRAM OF TRANSMITTER, RECEIVER AND AERIAL SWITCH.

power circuit is to prevent the sending apparatus from being operated while the receiving instruments are connected with the aërial and ground, and so preventing *burn-outs* and perhaps a lot of other damage.

But when the lever of the aërial switch is up the receiving tuning coil is connected directly with the aërial and ground wires, through the contact springs I and H. The high-frequency currents set up in the aërial wire by the incoming electric waves cannot flow into the transmitter, for the break in the circuit formed by the anchor-gap prevents the feeble current from jumping across and flowing this way, so that all of the current must flow through the receiving tuning coil.

It will be seen, then, that the sending tuning coil is connected with the ground wire both when sending and receiving. This does not matter in the least when receiving, for the currents which flow into the transmitter when you are receiving by way of the ground wire only add to the capacity of the ground, and this helps rather than hinders.

When the high-frequency currents from the aërial wire surge through the receiving tuning coil and to the ground, the current also flows through the closed circuit which includes the tuning coil, the condenser and the detector. The crystal detector changes the high-frequency currents into a direct current and this feeble direct current flowing through the magnet coils of the telephone receiver sets the diaphragm to buzzing and the ear reads off these sounds as dots and dashes.

If a dry cell and a potentiometer are used with a crystal detector to strengthen the signals, you must take care to have the current from the dry cell flow in the same direction as the direct current produced by the detector. Otherwise the signals will be weakened.

When you are through operating, throw the aërial switch halfway between the upper and lower contact springs, throw off the power switch and, if you are to be gone for any length of time, throw the lightning switch outside the window so that the aërial is connected direct to the ground.

CHAPTER IV

TUNING TRANSMITTERS AND RECEPTORS

Mechanical Tuning.—If you will tie two pendulums to a string stretched between two supports and set one of the pendulums swinging you will have a very good *demonstration* of tuning and what tuning means in wireless telegraphy.

The string which is stretched between the supports should be about two or three feet long and not too tight. Take two marbles of the same size, say *glassies*, and fasten a piece of string 12 inches long to each of them with sealing wax.

Tie the free ends of the strings about 12 inches apart to the stretched string as shown in Fig. 159. We will call the left-hand pendulum the transmitter and the right-hand pendulum the receptor, and mark them A and B.

If, now, you set the pendulum A to swinging, the other pendulum, B, will soon begin to swing also, the *energy* of pendulum A being *transmitted*, or carried, along the stretched string to the pendulum B.

Now make another pendulum using a marble of the same size as before, stick a piece of string 9 inches long to it and fasten the *free end* of the string to the stretched string between the pendulums A and B. Set the pendulum A to swinging again and you will see that while the pendulum B will swing as before, the short pendulum—which is not in tune with the other—will remain quiet.

Finally lengthen the string of the middle pendulum until it is 15 inches long and tie it to the stretched string. Set the pendulum A to swinging once more and again you will find that while the pendulum B swings in response to it the long pendulum will remain still just as the short one did.

It must be clear, then, that the length of the strings and the size of the marbles are the things which control the swinging of the pendulums, or, as we would say in wireless, these are the *factors which determine their periods of oscillation.*

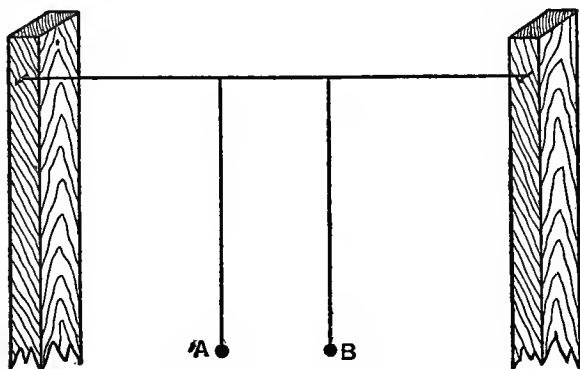


FIG. 159.—A PAIR OF TUNED PENDULUMS.

Electrical Tuning.—Another simple experiment which shows exactly how electric circuits are tuned can be easily made if you have a small induction coil and a pair of Leyden jars.

Take two Leyden jars of the same size, or *capacity*, as it is called, and set them a foot or two apart on a wooden base as shown in Fig. 160. Cut off two pieces of copper wire, No. 4 Brown and Sharpe gauge, each 18 inches long, bend these wires and fix them to a wood support (not shown in the cut) so that one end of one wire makes contact with the tin foil inside the Leyden jar A and one end of the other wire makes contact with the tin foil on the outside of the jar. Bend the wires over to form a spark-gap B, $\frac{1}{16}$ inch long and round off the ends of the wires with a file.

Cut off two more pieces of No. 4 Brown and Sharpe gauge copper wire 20 inches long and bend these as shown at C, Fig. 160. Fasten these to a wood support and have one end of one of the wires make contact with the tin foil inside the Leyden

jar and the other end make contact with the tin foil outside the jar as before. Bend over the free ends of the wire so that they will be about 3 inches apart and parallel for about 10 or 12 inches.

Stick a strip of tin foil, one end of which is pointed, to the tin foil inside of the jar C and bend it over the top of the jar and down until the pointed end comes to within $\frac{1}{2}$ inch of the outside tin foil as shown at D. Bend the ends of a piece of

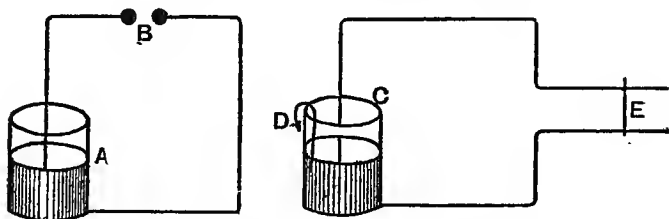


FIG. 160.—A PAIR OF TUNED LEYDEN JARS.

copper wire $3\frac{1}{2}$ inches long and slip it between the *parallel* wires.

If, now, you will charge the Leyden jar A with an induction coil it will discharge across the spark-gap B, and if the circuit which includes the Leyden jar C is in tune with the circuit A, that is if the electrical dimensions of the jars and the wires of both circuits are exactly the same, then the circuit C will respond to the high-frequency currents, or electric oscillations, as they are called, of the circuit A and sparks will jump across the little spark-gap at D of the circuit C.

If when the sparks jump across the spark-gap B of the transmitting circuit and sparks do not jump across the little gap D of the receiving circuit you will know that the circuit C is not in tune with the circuit A, but you can easily put them in tune by moving the wire slider E one way or the other on the parallel wires when you will find a place where the jar C will spark across the gap D. Then you will know that the circuits are in tune.

From this simple experiment you will learn many things

about wireless in general and tuning in particular which will be of use to you in the operation of your station.

Electric Oscillations.—In making the experiment with the pendulums you will have noticed that a short pendulum swings, or oscillates, very fast while a long pendulum oscillates slowly, and this is also true of a circuit of small and large electrical dimensions in which electric oscillations surge.

Just as the length and size of a pendulum governs the time of its swings, or its period of oscillation as it is termed, so the electric oscillations surging in a circuit will be as fast or slow as we want them, that is if we make the circuit electrically small or large. This sounds like magic but it is really very simple.

It is done in this way. Just as a pendulum has length, breadth and thickness so every electric circuit has what we may call three electrical dimensions or properties, and these are called *resistance*, *capacity* and *inductance*, and by varying these three things we can make the electric oscillations as fast or as slow as we want them, nearly.

Resistance.—If you try to kindle a fire like a South Sea Islander, that is by rubbing a stick of hard wood on a block of soft wood you will notice that the stick will not slide over the block very easily and this is caused by *friction*. If you put soap on the block the stick slips over it with little effort, for soap lessens the *friction*.

When a current flows through a wire it is opposed by something that is very much like friction and this is called the *resistance* of the wire. Copper wire offers less resistance, or friction, to the passage of an electric current than any other metal except silver and this is the reason copper is used for conductors of electricity.

In wireless the resistance of the wires need not trouble you, for electric oscillations stick to the outside of the wires and if the wires are large and every joint and contact is well made there is very little resistance to overcome. In the sending circuit the spark-gap must not be too long or the electric oscillations will meet with a high resistance due to the air and the

currents will not pass. As far as tuning is concerned you need not bother with the resistance of the circuits.

Capacity.—A gallon bucket will hold just four quarts and no more, but there are some contrivances which are never full until they burst. If you force gas into a rubber bag you cannot say it is full until it has reached the point where it explodes.

There are devices made for holding electricity but they are neither buckets nor gas bags. To hold electricity a condenser, with whose construction you are acquainted, is used, and a condenser is like a gas bag in that it is never full until the point is reached where the current which charges it breaks it down.

Different from fluids and gases, a charge of electricity always sticks to the outside of a sheet of metal and hence a sheet of tin foil $\frac{1}{16}$ inch thick will hold just as much electricity as a copper plate 1 inch thick of the same surface area, or size, that is if we neglect the edges.

All metals have a capacity for electricity but to get a large capacity into a small space leaves of tin foil separated by sheets of glass or mica or paper are used, and a device of this kind is called a *condenser*.

A condenser will slow down an electric oscillation flowing in a circuit, for the current has to charge the condenser each time before the condenser discharges itself.

The size of a condenser has the same effect on an electric oscillation that the length of a pendulum has on its swing; hence, if we want fast oscillations we must use a condenser of small capacity and if we want slow oscillations we must use a condenser of large capacity.

Inductance (Pronounced in-duk'tance).—It takes about $\frac{1}{2}$ second for a boy to throw a ball counting the time from the instant he begins to throw until the ball leaves his hand; and if we measured the time it takes him to catch the ball we would probably find it to be in the neighborhood of $\frac{1}{4}$ of a second.

It takes time for a street car to get up speed and when once going it takes time for it to stop. Everything we know of

takes time to start and time to stop and electricity is no exception to the rule. Electricity travels 186,500 miles a second, which is just the speed of light—and yet it takes time for it to start and once started it takes time for it to stop.

This property of balls and cars and things to resist being moved when at rest and to keep on going when once in motion is called *inertia*, and the *inertia* of an electric current is called its *inductance*.

If the electric oscillations are flowing through a straight wire circuit, as in the tuned circuits shown in Fig. 160, it does not take as long for the oscillations to start and stop as it does if the wire is coiled up, for the inductance of a straight wire is not nearly as great as that of a coiled wire, but in either case the electric oscillations are slowed down according to the amount of inductance of each.

Hence tuning coils are not only the most compact, but they are also the most effective forms of *inductances*.

Open Oscillation Circuits.—In wireless telegraphy the aerial wire system forms an *open oscillation circuit*. In a simple open oscillation circuit the spark-gap is formed between the ends of the aerial and ground wire as shown in Fig. 161. Since no tuning coil or condenser is used with this open oscillation circuit the *inductance* and *capacity* are laid evenly along the straight wires, and both the inductance and the capacity are, therefore, very small.

For this reason an electric charge produced by an induction coil on the aerial and ground wires in the small transmitter described in Chapter I, Part I, and which sets up the oscillating currents, is very small; as these currents are rapidly changed

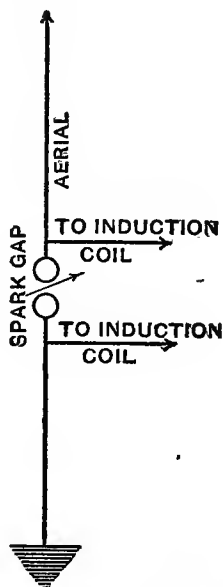


FIG. 161.—NON-TUNED OPEN OSCILLATION CIRCUIT.

into electric waves the current only makes two or three swings, or oscillations, before it is entirely gone, or *damped out*, as it is termed, as shown in Fig. 162.

After these electric oscillations are damped out, or changed into electric waves, the aerial and ground wires are again charged by the induction coil, another spark takes place and two or three more oscillations surge in the aerial wire, and so on.



FIG. 162.—STRONGLY DAMPED OSCILLATIONS.

A straight aerial wire system sends out electric waves which are about four times the length of the aerial, and since there are neither tuning coils nor condensers connected with it the length of the electric wave which it sends out depends entirely upon the length of the aerial wire itself.

Closed Oscillation Circuits.—A pendulum which makes

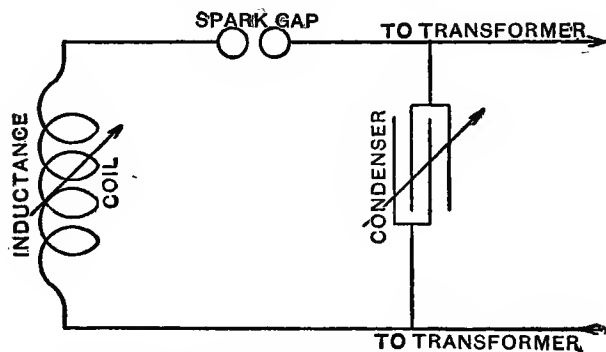


FIG. 163.—TUNED CLOSED OSCILLATION CIRCUIT.

only two or three swings would cause another pendulum of unequal length to swing but very little if at all. In order to make another pendulum respond freely the first pendulum must swing a large number of times before it dies out.

And this, too, is what an electric current in a sending aerial

wire must do in order to send out trains of waves to long distances and make a properly tuned receiving aerial respond to these waves.

Of course a simple open receiving aerial will respond to a sending aerial of the same kind but it does so by sheer force of the electric splash sent out and not because the receiving aerial is in any way tuned to the sending aerial.

Now to make a high-frequency current in a sending aerial oscillate a large number of times every time a spark jumps

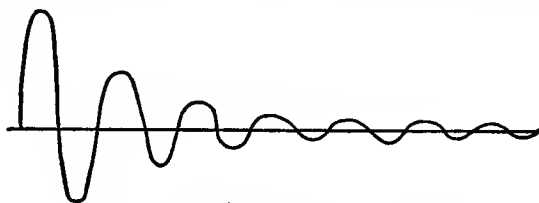


FIG. 164.—FEEBLY DAMPED OSCILLATIONS.

across the spark-gap the aerial and ground must be connected with a closed circuit, that is a circuit which has a spark-gap, a condenser and a tuning coil, as shown in Fig. 163, and all of which are adjustable.

This closed circuit is just the same as the circuits of the tuned Leyden jars except that a coil of wire and a number of Leyden jars have been put in the circuit to give it more inductance and capacity, and as these are made adjustable the circuit is easier to tune.

The electric current in a closed circuit swings to and fro, or oscillates, a large number of times before it dies out as a closed circuit does not change the oscillating current into electric waves very freely and so the oscillations are strung out to a dozen or twenty swings as shown in Fig. 164, and these *feebly damped oscillations*, as they are called, are just the kind which are needed for wireless tuning.

Coupled Oscillation Circuits.—Since an open oscillation circuit, such as is shown in Fig. 161, changes the electric oscilla-

tions surging in it into electric waves so quickly it is exactly the thing needed for a sending circuit, but for the very reason that the oscillations are damped out so quickly it is a very poor arrangement for tuning purposes.

On the other hand a closed oscillation circuit, as shown in

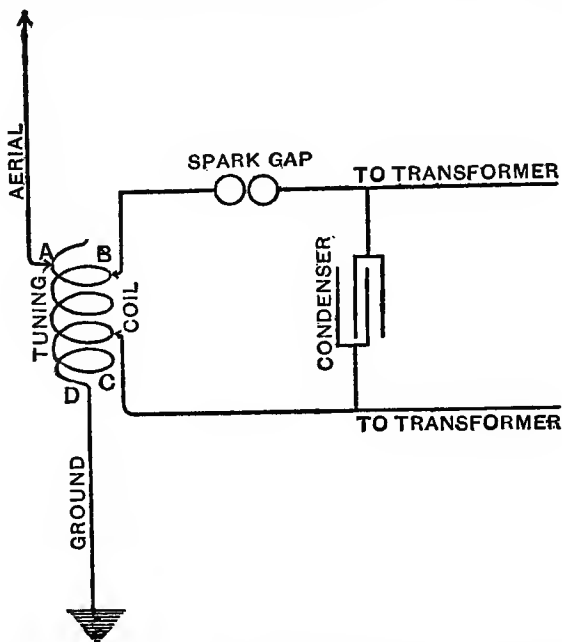


FIG. 165.—COUPLED OPEN AND CLOSED OSCILLATION CIRCUITS FOR TRANSMITTING.

Fig. 163, changes the electric oscillations surging in it into electric waves very slowly, but because the oscillations are so *feebly damped out* it is of no value as an aerial to send out waves.

To get in a measure the good effects both of the open and closed circuits so that long trains of strong electric waves will be sent out the two circuits are *coupled*, that is they are joined together.

There are different ways by which the aërial and ground wire can be coupled with a closed circuit, but the way we have chosen for the long distance set is that shown in Fig. 165 for the transmitter and Fig. 166 for the receptor. Joining the circuits together in this fashion is called a *direct*, or *conductive coupling*.

From what has been said it will be clear that when the open and closed circuits are coupled together they can be tuned to each other so that the electric oscillations in both circuits will surge together, or have the same *frequency*, as it is called. Likewise, the receiving station can be tuned to the sending station.

This is done by varying the capacity and inductance, which

means, of course, that more or less of the condensers are used and cutting in and out turns, or parts of turns, of wire of the tuning coils. As a matter of fact, both the transmitter and the receptor can be tuned by simply changing the positions of the clips and sliders on the tuning coils and without touching the condensers, or they can be tuned by varying the capacity of the condensers without changing the values of the tuning coils.

Action of a Tuned Transmitter.—Starting with 110 volt, 60 cycle alternating current taken from the mains of a lighting or power circuit and supposing the key to be closed, the cur-

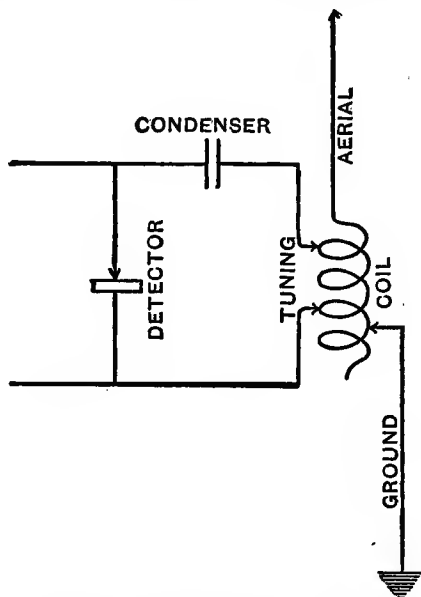


FIG. 166.—COUPLED OPEN AND CLOSED OSCILLATION CIRCUITS FOR RECEPTOR.

rent flows through the regulating resistance—in this case a water resistance—and through the primary coil of the transformer.

Since the current changes its direction 120 times a second no interruptor is needed in the primary circuit to set up alternating currents, by *electromagnetic induction*, in the secondary coil of the transformer. The current at the ends of the secondary coil changes its direction exactly the same number of times per second as the current which flows into the primary coil.

While the frequency is the same for both the primary and the secondary coils the *pressure*, or *voltage*, is stepped up about 100 times, that is the primary coil is wound with, say, 300 turns of wire, and the secondary coil is wound with 30,000 turns of wire, the voltage is increased 100 times and 100 times 110 equals 11,000 volts at the ends of the secondary coil.

The ends of the secondary coil of the transformer are connected with the Leyden jar condenser and this condenser is charged, (and discharged) every time the current changes its direction. Also every time the condenser is charged it discharges through the spark-gap and the turns of the tuning coil which are between the clips B and C, as in Fig. 165.

Now, the discharge of a condenser is always alternating, or *oscillating* as it is called, though both mean the same thing, and this oscillating current changes its direction anywhere from 100,000 to 1,000,000 or more times per second, depending upon the size of the condenser and the amount of inductance and resistance there is in the circuit.

These oscillating currents do not need a closed circuit to flow in, but they are so lively that they surge up to the end of the aerial wire and down through the tuning coil to the ground with amazing freedom. In order to get the best results a certain amount of inductance must be connected with the lower end of the aerial wire between the clips A and B of the tuning coil, and there must also be a certain amount of inductance between the ground wire D and the clip C of the tuning coil in order

to tune the aërial wire to the closed oscillation circuit if strong electric waves are to be sent out.

The chief points to be remembered are (1) that the frequency of the electric oscillations in the aërial wire system depends entirely on the capacity, inductance and resistance of the aërial wire and the closed oscillation circuit, and (2) that the length of the electric waves sent out by the aërial wire depends solely on the frequency of electric oscillation in the aërial wire.

The best and easiest way to tell when the aërial wire and the closed circuit are in tune is to use a *hot-wire ammeter*, but if you want to know exactly what wave length your aërial is sending out you must use a *wave-meter*. Both of these handy instruments will be described presently.

Action of a Tuned Receptor.—When the electric waves which are radiated, that is sent out by the aërial of a transmitter, strike the aërial connected with a receptor (see Fig. 166), the electric waves are changed into electric oscillations, and if the circuits of the receptor are tuned to the circuits of the transmitter

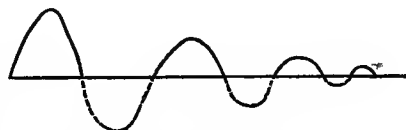


FIG. 167.—INTERMITTENT DIRECT CURRENT PRODUCED FROM ELECTRIC OSCILLATIONS.

the oscillations will have exactly the same frequency as those in the aërial of the transmitter which sent them out.

As the oscillating currents run up and down the aërial and ground wires they flow through the closed circuit in which the condenser and the detector are connected.

When the oscillating currents flow through the contact made by the phosphor-bronze point and the crystal of the detector, they flow very freely in one direction, but they have hard work getting through the contact again in the other direction. In other words the lower half of the oscillating current is cut off as shown by the dotted lines in Fig. 167, and in this way the oscillating current is *rectified*, which means that it is changed into a direct current.

The direct current produced by the detector is large enough to energize the magnet of the telephone receiver, and which in turn causes the diaphragm of the telephone receiver to vibrate accordingly. The vibrations of the diaphragm set up sound waves which the ear hears as buzzing dots and dashes.

The reason that a detector must be used is that the received electric currents oscillate so very fast that the diaphragm of the telephone receiver cannot begin to keep up with it and so a direct current must be used.

The purpose of using a dry cell is to add current to the direct current produced by the detector. It will be readily seen that the current from the dry cell must flow in the same direction as the *rectified current* of the detector or the two currents will oppose instead of help each other.

It is important that exactly the right amount of current from the dry cell should be used with the crystal detector and the potentiometer permits this to be done.

How to Make and How to Use a Hot-Wire Ammeter.—

When electric oscillations surge through a wire too small to carry the current easily the wire gets hot and it begins to stretch and this can be used to move a needle. This scheme is used in the hot-wire ammeter.

You can easily make a hot-water ammeter which will show when your sending circuits are in tune, but if you want a hot-wire ammeter with which to measure the amount of current in fractions of an ampere which is surging in your aerial you had better buy one.

Make a wood base $\frac{3}{4}$ inch thick, 5 inches wide and 6 inches long as shown in Fig. 168. Screw two small binding posts to the corners, and solder a piece of No. 30 copper wire, Brown and Sharpe gauge, about $3\frac{1}{2}$ inches long to the posts and see that it is taut.

To the middle of the wire solder another copper wire of the same size, about 1 inch long, and make a loop at the free end. To this loop tie a stout silk thread and also tie the thread to the index needle. Tie the other end of the thread to one end of a

spiral brass spring made of very thin wire and fastened to the base with a screw at its other end.

The index needle can be pivoted to the base by means of a pin but it must not wobble. The thread tied to the needle will keep it clear of the base. Make a cardboard scale and divide

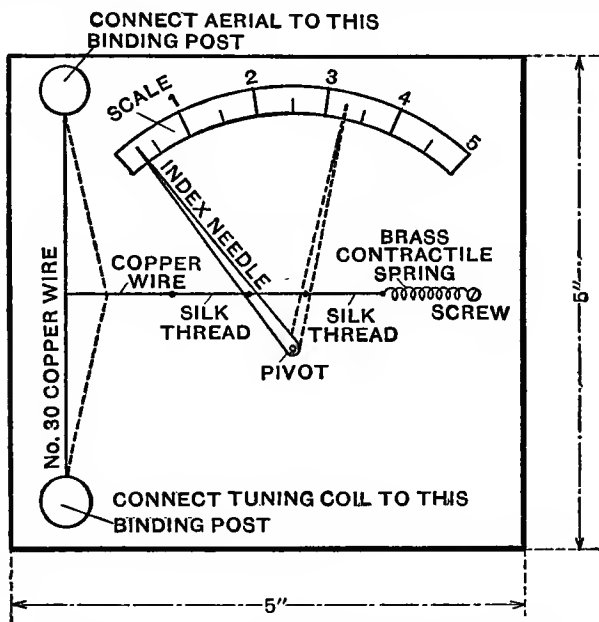


FIG. 168.—SIMPLE HOT-WIRE AMMETER—TOP VIEW.

it into say five divisions and tack it under the end of the needle. It can be marked with figures but unless the hot-wire ammeter is adjusted to read in amperes the figures will have no real value.

When the hot-wire ammeter is connected in between the aerial wire and ground and oscillations are surging through it the wire gets hot, owing to the resistance it offers to the flow of the oscillating currents and when it gets hot it begins to stretch. The brass spring which has been drawn out by the

wire when cold now begins to draw in, or contract, and this takes up the sag of the hot wire and pulls the needle across the scale. Fig. 169 shows the hot-wire ammeter in perspective.

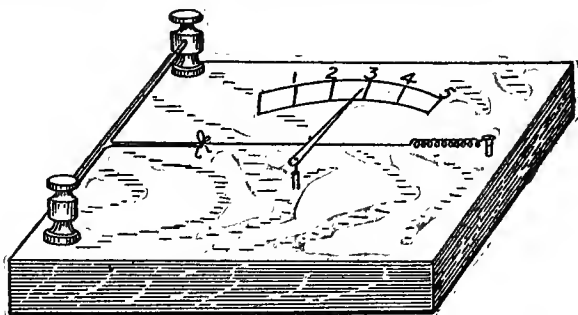


FIG. 169.—SIMPLE HOT-WIRE AMMETER COMPLETE.

By adjusting your condenser and tuning coil you will find that the needle of the hot-wire ammeter swings forth and back.

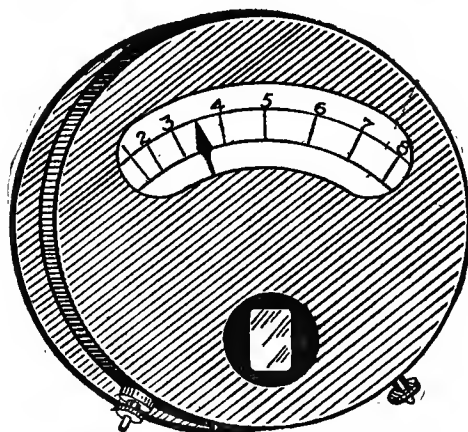


FIG. 170.—CHEAP HOT-WIRE AMMETER.

When the amount of current which flows into the primary coil of your transformer has been regulated just right by the water resistance, and the capacity of your condenser, the inductance of your tuning coil and the length of your spark-gap have been adjusted just right, the needle of

your hot-wire ammeter will swing farthest to the right of the scale and then you may be certain that your aerial wire and

closed circuit are in tune. A cheap and fairly good hot-wire ammeter as shown in Fig. 170 can be bought for from \$3.00 to \$6.00 of dealers in wireless apparatus.

Construction and Use of a Wave Meter.—As the Government will not permit a boy to send out electric waves which have a length of more than 200 meters¹—equal to 656 feet, the question naturally comes up as to how a fellow is to know

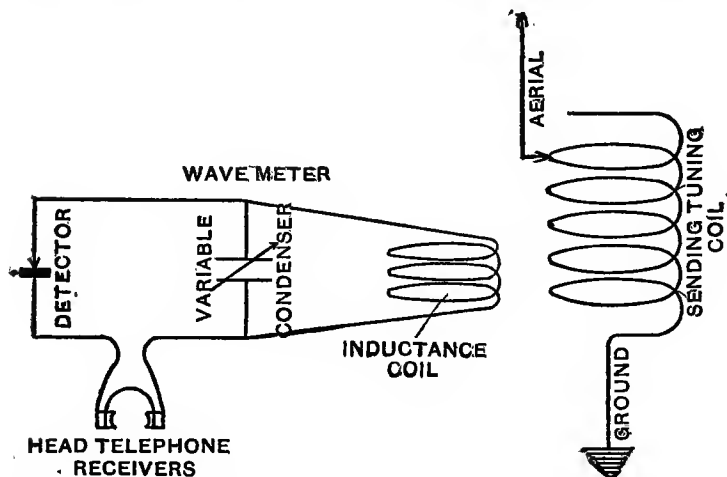


FIG. 171.—DIAGRAM OF WAVE METER AND SENDING TUNING COIL.

when his transmitter is sending out waves of the right length.

The answer is found in the use of a wave meter. If you have a wave meter you can do a lot of stunts with it, such as finding out if your transmitter is sending out one or two waves at the same time, the relative intensities of signals, the length of the waves sent out and the length of waves which are coming in.

A wave meter resembles a receptor without the aerial and ground wires, as it has a closed circuit formed of a crystal detector, a pair of head telephone receivers and a variable condenser; this closed circuit is connected with an inductance coil as shown in the diagram, Fig. 171.

¹A meter is equal to 39.39 inches.

A wave meter is formed of a rotary condenser whose capacity is variable and an inductance coil whose inductance is fixed and you can use your own detector and head telephone receivers with them so that the cost of a wave meter is very small.

The rotary variable condenser is built up of a dozen or

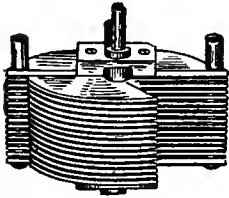


FIG. 172.—FIXED AND MOVABLE PLATES OF VARIABLE CONDENSER.

fifteen semicircular sheets of brass or aluminum rigidly fixed in a brass frame at a distance of $\frac{1}{16}$ inch from each other. Another dozen or fifteen semicircular sheets of metal are mounted on a spindle ending in a hard rubber disk handle on top of the condenser. These movable sheets of metal interleave, or slide between the fixed semicircles but do not touch them, as shown in Fig. 172.

When all the sheets are interleaved the capacity is the greatest and when the fixed and movable sheets are turned away from each other the capacity is very little or nothing. The condenser is placed in a brass case which is fitted with a hard rubber cover through which projects the spindle when the handle is screwed on.

On the top of the condenser is engraved a scale—something like that described for the hot-wire ammeter. This scale is divided into 150 spaces, called degrees. On the spindle is fastened a pointer and by turning the handle the amount of capacity of the condenser can be seen from the position of the pointer on the scale. The whole arrangement is shown in Fig. 173. This condenser can be used to mighty good advantage in place of the fixed condenser, described on page 95, Chapter II, Part II, for sharper tuning can be done with it than with the tuning coil.

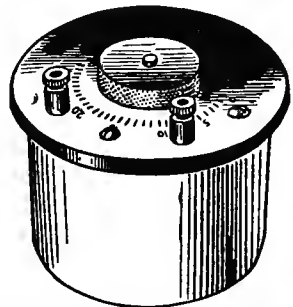


FIG. 173.—THE CONDENSER COMPLETE.

The inductance coil of the wave meter is made of about 25 feet of insulated wire wound in the groove of a disk or on a spool. The ends of the inductance coil are connected to a pair of binding posts, and which in turn are connected to the binding posts of the variable condenser as shown in Fig. 174.

With a wave meter of this type the length of electric waves from 150 meters up to 600 meters can be measured, and as a 600 meter wave length is the standard used by the Government

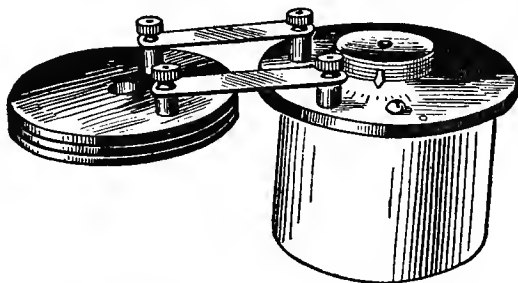


FIG. 174.—THE WAVE METER COMPLETE.

and commercial stations this is large enough for all your needs.

To use this wave meter disconnect your detector and head telephone receiver from your tuning coil and condenser and connect them to the binding posts of the variable condenser. Set the inductance coil of the wave meter close to and in parallel with the tuning coil of your transmitter as shown in Fig. 171.

The wave meter with the detector and head telephone receiver is entirely separate and distinct from the transmitter whose wave length is to be measured, but is acted upon by the currents flowing through the tuning coil of the transmitter just as the secondary coil of a transformer is acted upon by a current flowing through its primary coil.

When the key of the transmitter is closed, buzzing sounds are heard in the telephone receiver and as the capacity of the variable condenser is changed these sounds become fainter or stronger. When the sounds are loudest the circuits of the wave

meter and the transmitter are in tune, that is the electric oscillations in both circuits have the same frequency.

Now by noting the number on the scale on which the pointer of the condenser rests and consulting a curve sheet which goes with the wave meter, the wave length your transmitter is sending out can be read directly in meters.

Cost of hot-wire ammeter when bought of dealers..	\$3.00 to \$10.00
Cost of hot-wire ammeter when home-made.....	.50
Cost of variable rotary condenser when bought of dealers...	4.50
Cost of wave meter as shown in Fig. 174.....	6.00

PART III
CONTINUOUS WAVE WIRELESS
TELEGRAPHY AND TELEPHONY
CHAPTER I
THE NEW WIRELESS

In the first part of this book I told you how to make and use *spark* wireless telegraph sets. The electric spark system can be used only for wireless telegraphy, while the electric *arc* system was the only one known until quite recently that could be used for wireless telephony. Now, as I have explained in an earlier chapter of this book, the electric spark sends out *damped* or *discontinuous* waves while the electric arc sends out *undamped* or *continuous* waves.

With the advent of the arc system of telephony the advantageous properties of undamped or continuous waves over damped or discontinuous waves were learned and so great were these that every effort has been made to use the arc for telegraphy instead of the spark system. While the arc provides a simple means for setting up continuous waves, it is not an easy system to operate, though it has been used for the last fifteen years for wireless telegraphy. About as many years ago the two-electrode-vacuum tube was discovered to be a detector of electric waves and then the big improvement came when the third electrode, or *grid*, was added to it.

Further researches showed that the reason the three-electrode-tube detector was more sensitive than the crystal detector was because it acted at the same time as an *amplifier* of the oscillations set up in the receiving circuits. Then came the improvement of the *regenerative*, or *feed back*, *circuit*, in which part of the oscilla-

tions that are set up in the aerial wire system are continually fed back through the tube and this amplification increases the sensitiveness of the receptor enormously.

Since the vacuum tube acts as an amplifier as well as a detector, the next step was to employ one or more of the tubes as amplifiers, and when a detector with two amplifiers is used there is enough power available at audio frequencies to operate a large magnet and this in turn will make a diaphragm vibrate so forcefully that the incoming signals, voice, or music can be heard a block away—and there you have your *loud speaker*.

When the vacuum tube acts as an amplifier, it means simply that it is producing more and larger sustained oscillations—these are the kind that send out continuous waves—so the next step was to make tubes that were especially adapted to setting up powerful oscillations and these have been the means, not of making wireless telephony possible as one of the current newspaper writers put it (my oscillation arc of 1899 did that), but of making it easy to keep the sustained oscillations going once that they were started.

When I was experimenting with my rotating oscillation arc in Newark, N. J., in 1908–1910, the wireless boys in the Oranges, in Montclair, and other nearby towns used to tune in and *get* what we were saying into the transmitter. We were *broadcasting* then, but this was a phase of wireless telephony that we were not at all interested in; rather what we wanted and were striving for was *selective secrecy*, but this has not yet been invented.

The boy amateur has been getting broadcasted speech and music ever since, but it is only recently that men have become interested in wireless telephony as an indoor sport. It was the boy amateur who worked up the enthusiasm of the grown-ups and these latter have just waked up to what the boys have been alive to these many years; that is, that wireless telephony is the most wonderful electrical invention of this or any other age.

The big electric companies and others have fitted up powerful transmitting stations which, as everybody knows, send out daily telephone messages and music on wave lengths of something less than 400 meters. You can receive the programs of news, stories,

music, songs, etc., from nearby broadcasting stations with a cheap crystal detector receiving set; from a farther distance and better with a vacuum tube detector receiving set; still more distant stations and louder with a regenerative vacuum tube detector receiving set; from halfway across the continent and loud enough to be heard in a hall with a two-stage amplifier receiving set and a loud speaker, and, finally, with a two-stage radio frequency amplifier and a three-stage audio frequency amplifier it is possible for you to hear what the Eiffel tower station at Paris is sending or to get the big government station at Honolulu. Such wonders so easily within your grasp is an all-sufficient reason why you should lose no time in stringing up your aërial, hooking up your receiver and hearing all that the world and his wife are saying about people, events, and things that go to make up the news of the day.

CHAPTER II

VACUUM TUBE RECEIVING SETS

In all of the chapters that have gone before on wireless telegraphy the oscillations in the aerial, which send out the waves, were set up by an *electric spark*. Oscillations of this kind die out rapidly like the vibrations of a steel spring, that is, they are *damped* more or less as shown at *A* in *Fig. 175*, and hence the waves are discontinuous or *periodic* as it is called.

Such waves are not suitable for sending out speech and music, as there is a long time-interval between each train of oscillations which produce them, as shown at *B*. In the early days of wireless telephony the only known means for setting up *sustained oscillations* (see *C*) was with an electric arc. Waves radiated by sustained oscillations do not die out but have a constant amplitude and they are, therefore, *continuous waves*, or *C W* as they are called for short.

Continuous waves have many advantages over periodic waves and they are not only being used for wireless telephony, but for wireless telegraphy as well. Now, in the very nature of things, the transmitting apparatus should be described first, but since nearly every one is interested in receiving wireless telephone messages and very few are concerned with the sending of such messages, I shall reverse the usual order and explain the various kinds of receiving sets first and then take up the transmitting sets.

The Vacuum Tube Detector.—While you can receive speech and music with any of the crystal detector sets I have described

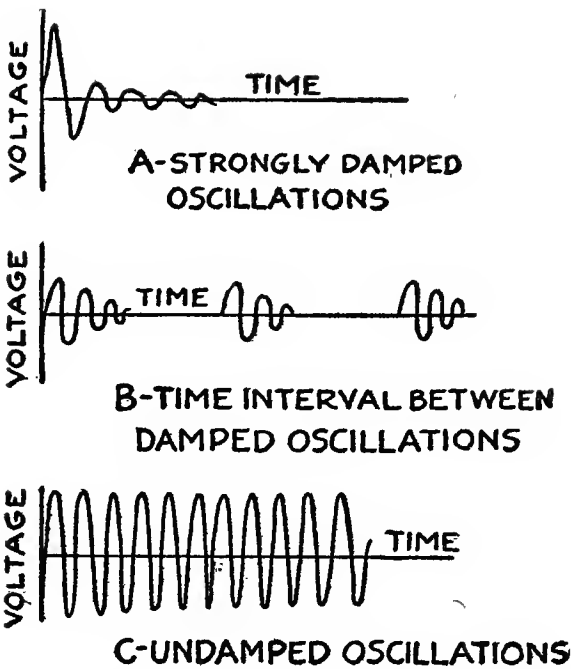


FIG. 175.—OSCILLATIONS OF A SPARK DISCHARGE.

A and B show Oscillations Set Up by a Spark Discharge. C shows Oscillations Set Up by an Arc and a Vacuum.

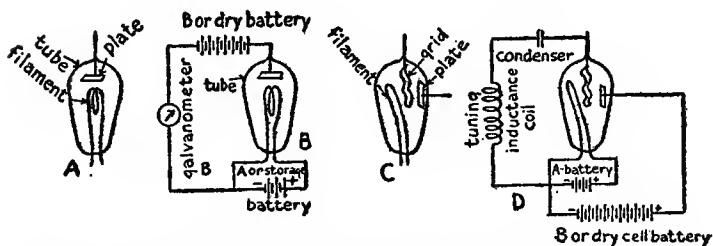


FIG. 176.—DEVELOPMENT OF THE THREE-ELECTRODE VACUUM TUBE DETECTOR.

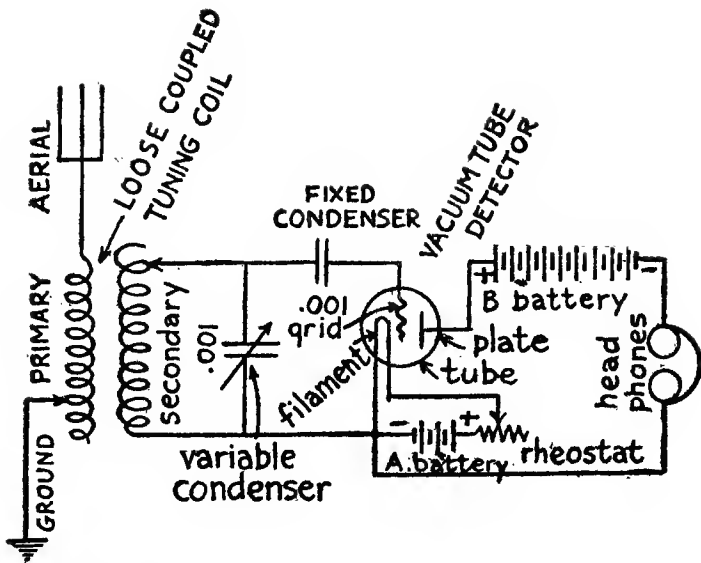
in the foregoing chapters the latest and best sets use a *vacuum tube detector*,¹ as it is called. The vacuum tube detector is far superior to the crystal detector, for it needs (1) very little adjustment, (2) it works uniformly, and (3) it is much more sensitive than the latter.

What the Vacuum Tube Detector Is.—You know, of course, that if an incandescent lamp has its filament broken a current will not flow through it. If, however, it were possible to heat one or both of the ends of the filament red or white hot, then the current would flow through it and bridge the gap. Since the filament is in a bulb from which the air has been pumped out you may wonder how it would be possible to perform this experiment. There are several ways of doing it, but an easy way to prove it is to seal an unbroken filament in the bulb with its ends projecting through the bottom and a little metal plate sealed in the bulb with a wire attached to it and the free end brought out through the top as shown at *A* in *Fig. 176*.

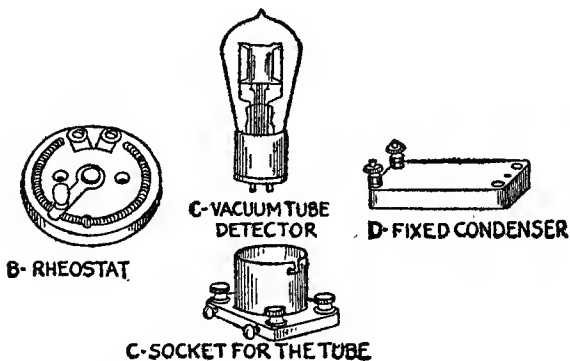
Since all vacuum tube detectors and amplifiers use 6 volts to heat the filament we will suppose that this one also does, so connect a 6-volt (that is, a 3-cell) storage battery, called the *A battery* in wireless, to the filament, when it will heat it to *brilliancy*, as the operators say. Now connect the — or *negative electrode* of the battery to one post of a galvanometer and the other post of this to the negative or zinc tap of a 22½ volt dry battery, called the *B battery*, and the positive or carbon tap of this to the metal plate of the tube, as shown at *B*. You will now find that a current is flowing in the plate circuit which shows that it must be passing through the gap between the filament and the plate. This phenomenon was discovered by Edison many years ago and it is still called the *Edison effect*.

A dozen years or so ago J. A. Fleming found that the Edison two-electrode tube *rectified* oscillating currents just as a crystal detector does, and hence, like the latter, it could be used as an electric wave detector. He also found that by keeping the plate charged with *positive* electricity its sensitiveness was greatly in-

¹This is known in England as the thermionic valve.



A. FIG. 177.—CONNECTIONS FOR A SIMPLE VACUUM RECEIVER.
How a Simple Vacuum Tube Receiving Set Is Connected Up.



B, C, and D. FIG. 177.—ADDITIONAL PARTS FOR A SIMPLE VACUUM TUBE RECEIVING SET.

creased. To do this, all that is necessary is to put a $22\frac{1}{2}$ volt (that is a 15-cell) dry battery, called the *B battery*, in the plate circuit, as at *B*.

Later experiments by other investigators proved that if a third electrode formed of metal gauze or a grid of fine wires, and which is called the *grid*, is placed between the filament and the plate as shown at *C* the tube will, when properly connected up and energized, act as a marvelously sensitive detector of electric waves. The way in which the filament, the plate and the grid are connected with the *A* and *B* batteries and the closed oscillation circuit of a receiving set is clearly shown at *D*.

A Simple Vacuum Tube Receiving Set.—The simplest vacuum tube detector receiving set that can be used is shown in the wiring diagram at *A* in *Fig. 177*. It consists of (1) a *tuning coil* of either the three-slide, *single-coil type* described in Part II, Chapter IV, or the *loose-coupled tuning coil* described in Part II, Chapter VIII, which is very much better; (2) a variable *condenser*, also described in Chapter VIII; (3) an *A*, or 6-volt *storage battery*; (4) a *rheostat*, which is a variable resistance for controlling the filament current and which is shown at *B*; (5) a *B*, or $22\frac{1}{2}$ volt *dry cell battery* for charging the plate of the detector tube positively; (6) a *three-electrode-vacuum tube detector* with a socket (see *C*); (7) a .001 *microfarad fixed condenser* as at *D*, and (8) a pair of head *telephone receivers*, or *head-phones* as they are called, wound to at least 500 ohms resistance while 2,000 ohm phones will be far more sensitive. Mount the tuning coil, condenser, detector, and rheostat on a base board or a panel and you are ready to wire the parts together.

Begin by connecting the leading-in wire of the aerial to one end of the primary of your tuning coil as shown in the wiring diagram at *A* in *Fig. 177* and the slider of the primary with the ground. Connect one end of the secondary coil with the grid of the detector tube and connect the other end of the secondary to one terminal of the head-phone, the other terminal of this with the *negative* or zinc tap of the *B* battery and the *positive* or carbon tap of the latter with the plate of the detector.

Next connect the negative electrode of the *A* battery to one of the terminals of the filament of the detector and also to the wire that leads from the secondary coil to the head-phones. Connect the other end of the filament with one of the posts of the rheostat

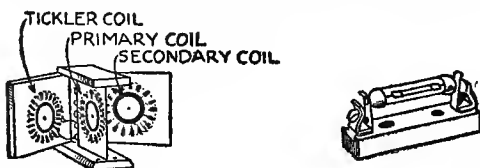
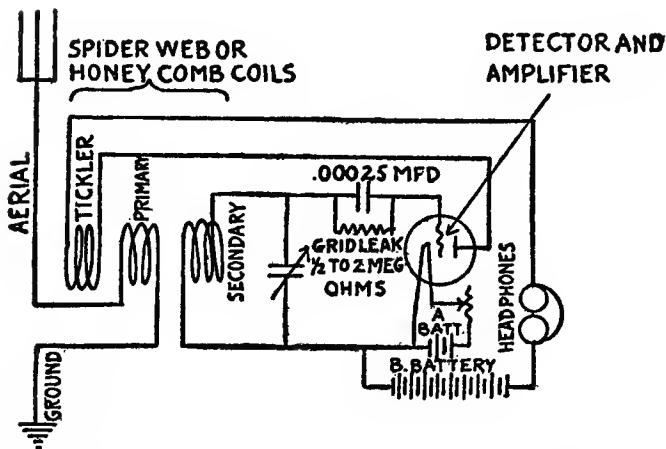


FIG. 178.—PARTS FOR A SIMPLE REGENERATIVE RECEPTOR.

A, Spider-web Tuning Coils.
B, Grid Leak Resistance.



C, Wiring Diagram for a Simple Regenerative Receiving Set.

and the variable contact of it to the positive electrode of the *A* battery. Finally connect the variable condenser across the secondary of the tuning coil and you are ready to tune in either amateur stations that work on a 200-wave meter or less or broadcasting stations that send out on waves of from 350 to 400 meters.

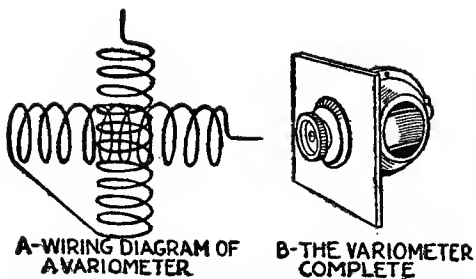
A Simple Armstrong Regenerative Receiving Set.—Not

only can a vacuum tube be used as a detector of electric waves but it will also act as an *amplifier* and, curiously enough, it will act as a detector and an amplifier at the same time, provided a part of the oscillating current is fed back through the tube. This interesting and useful discovery was made by E. H. Armstrong in 1915. By using the Armstrong regenerative *feed-back*, or some modification of it, the vacuum tube will have its sensitiveness increased manifold, and nearly all the good receiving sets are now provided with it.

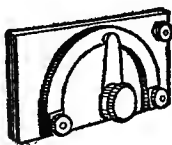
For this receiving set you will need (1) a tuning coil that has three separate coils on it, namely, (a) a *primary*, (b) a *secondary*, and (c) a *tickler*, as the third coil is called. This tuning coil can be in the form of a loose coupler having its primary coil fixed, its secondary coil sliding over it and its tickler coil sliding inside of it, or it can be formed of three flat coils, called *spider-web* coils as shown at *A* in *Fig. 178*, or *honeycomb* or other compact coils can be used. These coils can be bought ready wound, the smallest having a range of wave lengths from 180 to 400 meters with a .001 *microfarad* variable condenser while the next size will give you a range of waves from 180 to 1,000 meters with a variable condenser of the same *capacitance*. You can then mount them so that they will swing close to and away from the primary and so vary the *coupling*.

Besides the tuning coils you must also have (2) a .001 *mfd.* variable condenser; (3) a .00025 *mfd.* fixed condenser, and (4) a grid leak, see B, of 1 *megohm* resistance. You will also need (5) an *A* battery; (6) a *rheostat*; (7) a *detector tube*; (8) a *B* battery, and (9) a pair of *head-phones* all as described for the preceding receiving set.

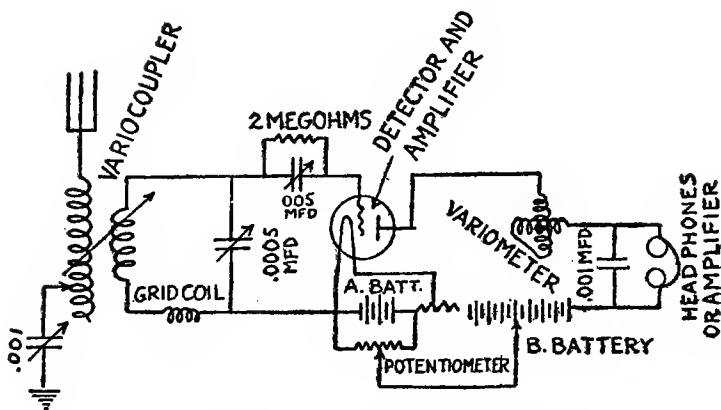
To wire up the set connect one end of the primary coil, which is the fixed coil, to the leading-in wire of the aerial and the other end of the coil with the ground as shown at *C* in *Fig. 178*. Now connect one end of the secondary coil with one side of the fixed condenser and the other side of this to the grid of the detector, and shunt the grid leak around the condenser. Connect the other end of the secondary coil to the negative, or zinc, tap of the *B* bat-



A and B show the Variometer.



C, A Graphite Potentiometer.



D, A Regenerative Receiving Set with Variometer.

FIG. 179.—REGENERATIVE RECEPTOR WITH VARIOMETER.

tery and the positive, or carbon, tap with one of the terminals of the head-phones. Connect the other terminal of the latter to one end of the tickler coil and the other end of this to the plate of the detector.

Next connect one terminal of the filament with the wire connecting the secondary coil with the *B* battery, and connect the other terminal of the filament with the sliding contact of the rheostat; then connect one end of the rheostat with the positive electrode of the *A* battery; last of all, connect the negative electrode of this with the other terminal of the filament and you are ready to tune in for amateur or broadcasting stations.

A Regenerative Set with Variometer.—A *variometer* is a *kind* of tuning coil in which the primary coil is fixed and the secondary coil is mounted in the turns at right angles to it. Further one end of the primary is connected to one end of the secondary coil and it has no sliding contacts or other means of varying the inductance of the primary and secondary coils, but tuning is accomplished solely by varying the coupling between them.

The variometer consists of a fixed primary coil wound on a hollow spherical shell and a movable secondary coil which is likewise wound on a spherical shell; the latter is mounted on a spindle which is pivoted in the hollow shell and to this is fastened a knob and a pointer while a scale is mounted on the fixed coil or on a panel so that the relative positions of the two coils can be gauged. The advantage of using a variometer is that the receiving set can be tuned very sharp. The way the coils are connected together is shown at *A* in *Fig. 179* and the variometer complete at *B*.

To get the best results with a vacuum tube detector the potential or voltage of the plate must be very carefully adjusted and to do this a *potentiometer* is used. A potentiometer best suited for this work consists of either a semicircle of high resistance graphite on which a movable arm makes contact as shown at *C*, or a coil of high resistance alloy wire wound on a cylinder on which a slider makes contact as in a tuning coil. The ends of the graphite, or coil, are connected with the positive and negative electrodes of the *A*

battery while the sliding contact is usually connected with the ninth negative tap of the *B* battery; it then delivers a current of 18 volts and this with the current from the *A* battery gives a total of 24 volts, which may be cut down to the exact amount required.

For this set you will need (1) a *loose coupler*; (2) a *variometer*; (3) a .001 mfd. *adjustable condenser*; (4) two .0005 mfd. *adjustable condensers*; (5) a .001 mfd. *fixed condenser*; (6) a 2-megohm *grid leak resistance*; (7) a *grid coil*; (8) a *tube detector*, which also acts as an *amplifier*; (9) an *A battery*; (10) a *rheostat*; (11) a *B battery*; (12) a *potentiometer*, and (13) a pair of *head-phones*, or an *amplifier* can be connected in instead.

In wiring up the parts begin by connecting the leading-in wire to one end of the primary of the loose coupler; the other end of this to one side of the .001 mfd. adjustable condenser and the other side of the latter to the ground as shown in the wiring diagram at *D*. Then connect one end of the secondary of the loose coupler to one side of one of the .0005 mfd. condensers and the other side of this with the grid of the detector and shunt the grid leak around the condenser. Next connect the other end of the secondary coil with one end of the grid coil and connect the other end of this with one terminal of the filament of the tube. Shunt the other .0005 mfd. variable condenser across the grid circuit between the grid leak and the grid coil.

This done, connect the positive electrode of the *A* battery to the terminal of the filament that is connected with the grid coil and connect the negative electrode to one post of the rheostat and the movable contact of the latter with one of the taps of the potentiometer and the other tap of this to the positive side of the *A* battery. Now connect the sliding contact of the potentiometer with the negative, or zinc, tap of the *B* battery and the positive, or carbon, tap of this to one terminal of the head-phones; connect the other terminal of the head-phones with one end of the variometer and the other end of this with the plate of the detector. Finally shunt the fixed .001 mfd. condenser around the head-phones. In hooking up this receiving set have the wires that

connect with the detector as short as possible, as this will make it work better. Also where the set is to be used for receiving continuous wave signals, speech, or music you should place a sheet of copper, or *shield*, as it is called, back of the parts and between the loose coupler and the variometer.

A One-Step Vacuum Tube Amplifying Receiving Set, with Crystal Detector.—If you are using a crystal detector set and want to amplify the signals of it you can do so by getting the following additional parts and connecting them up as I shall explain farther on: assuming that your crystal detector set includes a loose-coupled tuning coil, a .001 mfd. variable condenser, a crystal detector, a pair of head-phones, and a .001 mfd. fixed condenser, then all you need is (1) a *vacuum tube amplifier* with a *socket*; (2) an adjustable *grid leak*; (3) a .001 mfd. *fixed condenser*; (4) an *A battery*; (5) a *rheostat*; (6) a *B battery*, and (7) a *potentiometer*.

There is no great difference in a vacuum tube detector and a *vacuum tube amplifier*, and one can be used in the place of the other. But manufacturers of tubes design them so that better results are had by using the tubes for the particular work they have to do, so you should always specify the kind of tube you want.

In this receiving set the oscillating currents set up by the received waves are amplified by the vacuum tube amplifier first at *radio frequency*, that is at the same frequency with which they surge in the aerial wire system; these amplified currents then flow through the crystal detector, where they are *rectified*, that is, converted into pulsating direct currents when they can flow through and will operate the head-phones.

In wiring up this crystal detector amplifying receiving set, the aerial and ground are connected to the primary coil of the loose coupler in the usual way as shown in the wiring diagram *Fig. 180*. Then connect one end of the secondary coil with one side of the fixed condenser and the other side of this to the grid of the amplifier tube. The other end of the secondary coil is connected with one terminal of the filament and to the negative electrode of the *A battery*. The other terminal of the filament is connected with one end of the rheostat and the movable contact of the latter

with the positive electrode of the battery. The variable condenser is now shunted around the secondary of the tuning coil.

This done, connect one end of the variable resistance with the plate and the other end of this with the positive, or carbon, tap of the *B* battery and then connect the negative, or zinc, tap with the

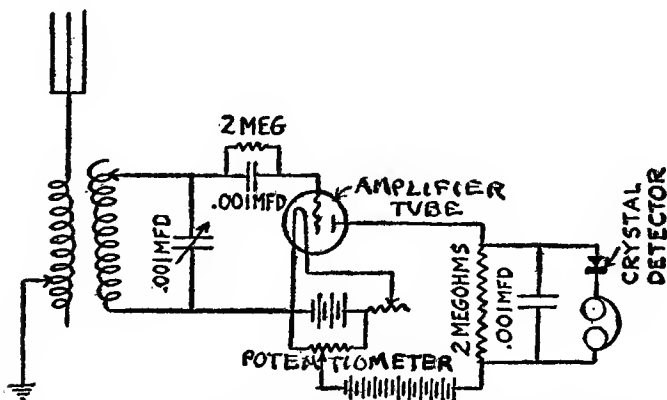


FIG. 180.—WIRING DIAGRAM OF RESISTANCE COUPLED AMPLIFIER RECEPTOR WITH CRYSTAL DETECTOR.

negative electrode of the *A* battery. Finally connect the metal point of the detector with the end of the resistance that is connected with the plate, connect the crystal of the detector with one terminal of the head-phones, the other terminal of the latter with the other end of the resistance and shunt the other fixed condenser around the resistance. While the potentiometer is not absolutely necessary, still much better results are had when it is used.

A Two-Step Vacuum Tube Amplifying Receiving Set, with Vacuum Tube Detector.—This set includes a vacuum tube detector and two vacuum tube amplifiers. In this case the first tube acts as the detector and the next two tubes as the amplifiers. You can use a single tube and have a *one-step amplifier* or you can use two or three tubes and have a *two- or three-step amplifier*, or

amplifiers in *cascade* as it is called. With a two- or three-step amplifier you can get stations a couple of thousand miles away with a single wire aerial, or nearer ones with a loop aerial in the house, or use a loud speaker with it, when every one in the room can hear the incoming messages or music.

For this receiving set you will need besides the parts described under the heading of a *simple vacuum tube receiving set* the following additional parts: (1) two *amplifying tubes*; (2) two *rheostats*; (3) two *.001 mfd. fixed condensers*; (4) two *B batteries*; (5) two *grid leaks*; (6) two *potentiometers*, and (7) two *audio frequency transformers*.

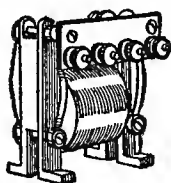
An *audio frequency transformer* (see *A* in *Fig. 181*), is simply a small iron core transformer that has a primary coil and a secondary coil wound on it. As iron tends to choke off the high frequency currents, the first vacuum tube must be the detector and the succeeding vacuum tubes are the audio frequency amplifiers.

The connections for the detector circuits are shown in the wiring diagram *B*, and are the same as those for a *simple vacuum tube receiving set*, except that instead of connecting in the head-phones at *a* and *b*, the ends of the primary coil of the audio frequency transformer are connected with them; then the ends of the secondary coil of the transformer *c* and *d* are connected to the grid and to the negative electrode of the *A battery*. In this way you can connect in as many amplifying tubes and transformers as you wish. Finally at *e* and *f* you can connect in either a pair of head-phones or a loud speaker.

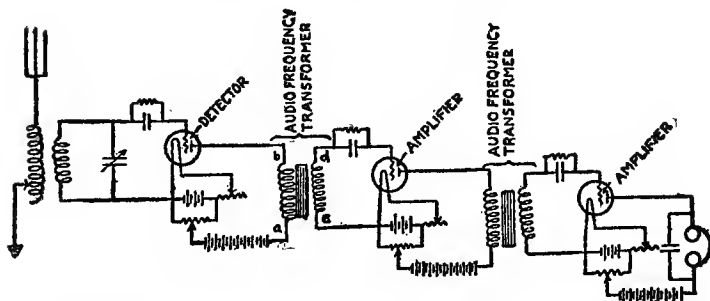
Connecting Vacuum Tube Filaments in Parallel.—While I have shown a separate *A battery* for each of the vacuum tubes at *B* in *Fig. 181*, for the sake of making the connections clear you really need to use only one battery. This you can do by connecting the filaments *in parallel*, as it is called, and which is clearly shown in the wiring diagram at *C* in *Fig. 181*. As storage batteries are expensive as well as bulky, this scheme saves money and space as well as a lot of useless wiring. A 40 volt *B battery* can be used and all of the plates energized by connecting them to it in parallel.

Intermediate Wave and Long Wave Receiving Sets.—The

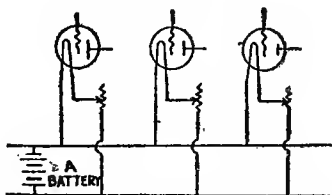
receiving sets I have described above will receive waves of from 150 to 400 meters in length so that you can get amateur and broad-



A, An Audio Frequency Transformer.



B, A Two-Step Vacuum Tube Amplifier Receiver with Vacuum Tube Detector.



C, Detector and Amplifier Tube Filaments Connected to A Battery in Parallel.

FIG. 181.—TWO-STEP AMPLIFIER RECEIVER WITH VACUUM TUBE DETECTOR.

casting stations with any of them. If, however, you want to receive intermediate waves, that is, waves up to 3,000 meters in length, or long waves, say up to 20,000 meters in length, which

are sent out by the big cableless stations of the world, then you will have to use compact coils of the *honeycomb* and *duo-lateral* kinds.

You can buy these coils already wound for different wave lengths and while the coils are not adjustable you can tune them to the wave length you want to receive by means of your variable condenser, which may have a capacitance of .001 mfd., or larger,

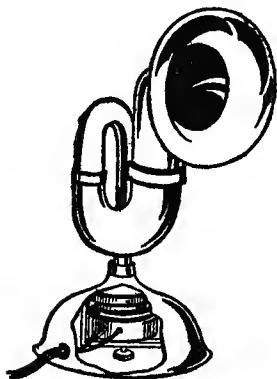


FIG. 182.—THE ARKAY LOUD SPEAKER.

for waves of whatever length. You can use coils for wave lengths up to 1,000 meters with a small aërial, but with coils for greater wave lengths than this your aërial must be proportionately longer and higher. Further, whatever the wave length of the coil you use for the primary in the aërial wire circuit, you should use a coil of the same wave length in the secondary circuit.

Connecting in a Loud Speaker.

—In ordinary telephone conversation you have sometimes observed that the receiver reproduces the speaker's voice loud enough so that it can be heard several feet away. This is because there is a large current strength flowing through the telephone magnet coils. The simplest type of loud speaker consists of a horn whose small end is fitted to a regular wireless head-phone as shown in *Fig. 182*;¹ in this case the horn amplifies the sound just as it does that of a phonograph receiver.

Loud speakers that are designed especially for the purpose are, however, much more powerful and the *Magnavox*² is one of the best on the market. It consists of an induction coil, the primary of which is connected with the receiving set where the head-phones are ordinarily connected in. The secondary coil leads up to and

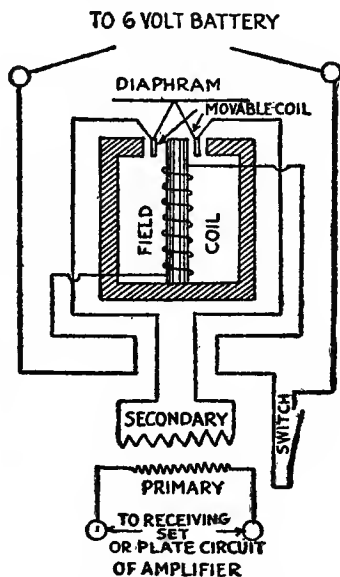
¹ Made by the Riley-Klotz Mfg. Co., Newark, N. J.

² Manufactured by Magnavox Company, of Oakland, Cal.

is connected with a movable coil and to this the diaphragm of the loud speaker is attached. The movable coil sets over the end of the iron core of an electromagnet and the field coil of this is connected to a 6-volt battery. A wiring diagram of this loud speaker is shown at *A* in *Fig. 183* and the device complete at *B*.



FIG. 183.—THE MAGNAVOX LOUD SPEAKER.



A, Wiring Diagram of the Magnavox Loud Speaker.

The Heterodyne, or Beat, Continuous Wave Telegraph Receiving Set.—Where wireless *telegraph* signals, that is, messages in the Morse code are sent out by continuous waves they cannot be heard with an ordinary crystal or vacuum tube detector receiving set. In order to receive them either (1) the sustained oscillations set up must be modified or broken up into groups at the transmitting station, or (2) the sustained oscillations set up in the receptor must be modified or broken up into groups at this end.

CHAPTER III

HOW VACUUM TUBE RECEIVING SETS WORK

How a Two-Electrode Vacuum Tube Works.—You have seen in the foregoing chapter that while a current will not flow between two cold electrodes in a vacuum tube, if one of them is hot the current will flow in the space between them. This is due to the fact that the hot electrode throws off minute particles of negative electricity or *electrons*, as they are called, and these form a conducting path between the hot filament and the cold plate.

Now since the electrons thrown off by the filament are negative particles of electricity and the filament itself is positively charged, the electrons after shooting out into space are attracted back to the filament in just the same way that if you threw a handful of marbles into the air they would be attracted back to the earth by gravity. The question is then how to make those that strike the cold plate remain there instead of returning to the hot filament; the answer is by charging the plate with positive electricity at a high voltage and then when the electrons reach it they will be attracted to it and stay there.

To charge the plate positively all you have to do is to connect the positive, or carbon, tap of a *B* battery with the plate and the negative, or zinc, tap with the hot filament as shown at *B* in *Fig. 176*, and once the electrons are started across the gap the circuit is complete and the current from the battery will flow through it. The moment you cut off the current of the *A* battery which heats

the filament the latter will stop throwing off electrons and consequently the battery current will cease to flow. Nor will the heated filament throw off electrons if you connect the positive tap of this with the plate, for like signs of electricity repel each other.

How a Three-Electrode Tube Works.—The easiest way to follow the action of a three-electrode tube detector is to find out first what takes place when (a) the temperature of the filament is changed, and (b) when the voltage of the plate is varied. When the temperature of the filament remains the same then, of course, the stream of electrons thrown off by it will be constant and, hence, the same number of them will reach the plate in the same length of time.

Now the number of electrons that are thrown off by the filament and strike the plate in a unit length of time is the factor that controls the voltage set up by the *B* battery whose current flows across the space between the plate and the filament. This being true, it is easy to see then that the higher the voltage of the *B* battery the larger will be the number of electrons that the filament will throw off and which strike the plate until a point will be reached when all of them will strike it and be captured by it. When this condition is reached the current is said to be *saturated*. So much for the action of the two electrode tube.

Where a three-electrode tube is used, that is, where a grid is placed between the filament and the plate the electrons thrown off by the filament, as well as the current from the *B* battery, have to pass through the meshes of the grid which is formed of loosely woven wire. The grid, you will observe, is in every receiving set connected with the aerial wire and when the incoming waves set up oscillations in the latter they produce a voltage on the grid and this acts on the electrons that pass through it on their way from the filament to the plate.

Suppose now the voltage impressed on the grid is *negative* and that it is *less* than the negative voltage of the filament which is set up by the *A* battery; in this case only a few electrons would be thrown off by the filament and these may still go through the grid and strike the plate; the result would be that a small portion

of the *B* battery current will still flow through the space between the plate and the filament. Further, it is possible to charge the grid negatively to such an extent that the filament will not throw off any more electrons and, consequently, no current can flow through the space.

But the grid is energized negatively and positively alternately and this results in letting the current from the *B* battery flow through the space from the plate to the filament and then cutting it off so that a pulsating direct current is formed and it is this that flows through the head-phones.

A factor which causes the saturation point to be more quickly reached is that the positive voltage of the grid makes it absorb some of the electrons and as the voltage rises a proportionately larger number of the electrons are absorbed by the grid. The number of electrons, then, from the filament that strike the plate is determined by the voltage of the grid and the current of the plate.

How the Vacuum Tube Works as a Detector.—Now let us find out how the vacuum tube works when it is connected up with the rest of the receiving apparatus as shown at *D* in *Fig. 176*. When the electric waves from a distant sending station strike the receiving aerial, oscillations are set up in it and as these surge to and fro through the primary of the loose coupler tuning coil their energy is transferred inductively to the secondary coil.

The closed oscillating circuit includes the secondary coil, the filament and the grid of the detector, and so the oscillating currents set up in the former surge through it between the filament and the grid, since the space is made conducting by the electrons. As these oscillations vary due to the different strength of the signals, or speech or music, the voltage of the plate is likewise varied, and so more or less current from the *B* battery flows through the circuit which includes the *B* battery and the head-phones.

As this is a direct current it acts on the head-phones at whatever frequency the wave trains are coming in, and these should be somewhere between 300 and 2,000 per second, as the ear can

hear any number between these limits to the best advantage and this is what is meant by the term *audio frequency*. The three curves given in *Fig. 185* show, *first*, the electric oscillations in the grid circuit; *second*, the variations impressed on the plate current; and, *third*, the pulsating direct current that is set up by the detector and which affects the head-phones.

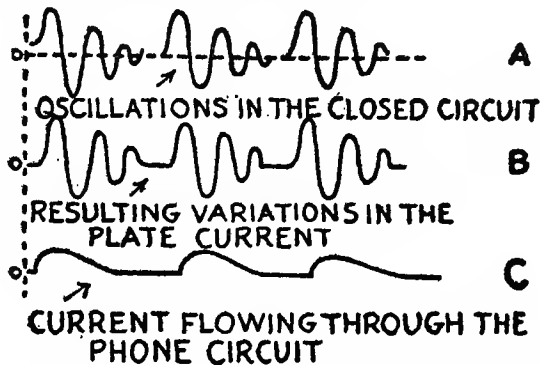


FIG. 185.—THE CONVERSION OF DAMPED OSCILLATIONS INTO PULSATING DIRECT CURRENTS.

In order to send out trains of waves at audio frequencies the transmitter must be of the spark type or, if undamped waves are used, then either a buzzer or a chopper must be employed where telegraph signals are sent out or a microphone where speech and music are sent out.

How to Treat Vacuum Tube Detectors.—Beginners in the wireless game are apt to do three things that greatly lessen the life of a vacuum tube detector; one of these is to bring the filament to brilliancy too quickly, another is to heat the filament to too high a temperature, and the other is to increase the plate voltage until it glows with a blue light. When you start to receive turn the current on through the filament very slowly by means of the rheostat until you have it up to brilliancy; don't make it too bright and keep the *B* battery voltage on the plate down to $22\frac{1}{2}$ volts or whatever it is rated for.

How the Vacuum Tube Works as an Amplifier.—From the foregoing explanation of how a vacuum tube detector works you have seen that when oscillations are set up in the closed oscillating circuit of a receiving set by the incoming signals or by speech or music the varying voltages that act on the grid cause like varying voltages to act on the direct current of the plate circuit. Now as the former control the number of electrons that are thrown off by the filament, so the electrons control the flow of the direct current and as this is much larger than the oscillations in the grid circuit, the tube acts like a Morse telegraph relay; that is, the feeble incoming currents permit a large direct current to flow through it and hence the vacuum tube acts as an *amplifier*. This relay action very largely accounts for the vacuum tube being so much more sensitive a detector than the crystal detector which simply converts the oscillations that pass through it into pulsating direct current, but does not augment, or amplify, them.

Amplifying Audio Frequency Oscillations.—Where a vacuum tube is to be used as an amplifier alone, that is, without any detector effects at all, it is only necessary to connect the primary of an audio frequency transformer, that is, one that has an iron core, to the plate of the detector and to the positive, or carbon, tap of the *B* battery, the other end of which is connected with the filament thus completing the circuit, when, of course, the latter is throwing off electrons. The secondary of the transformer is then connected to the grid and to the filament as shown at *B* in *Fig. 181*.

As currents of radio frequency, that is, high frequency oscillations, cannot flow through an ordinary iron core transformer, those of audio frequency which can flow through alone are amplified. In this way two or more amplifying tubes can be used before the current finally flows through the head-phones. A high resistance connected in between the plate and the positive tap of the *B* battery will serve in place of the audio frequency transformer, in which case the detector and head-phones are shunted around it as shown at *D* in *Fig. 180*.

How the Armstrong Regenerative Amplifying Circuits Work.—A way to make the detector tube serve as an amplifier to a much greater extent than it does when hooked up in the ordinary way is by using the Armstrong regenerative, or feed-back, circuits. There are different circuits by which this effect can be obtained, but all of them work on identically the same principle, which is this: oscillating currents are set up in the primary of the tuning coil and these set up oscillations in the secondary coil which act on the grid of the detector as described above.

One end of a *third* tuning coil, called the *tickler*, is connected to the plate, and so some of the energy of the oscillations of the primary coil is transferred to this and sets up oscillations in it; these surge through the circuit which includes the plate and the filament, and increase the current in the grid circuit. The result of this action is that a still larger current from the *B* battery flows through the detector tube and this amplification is repeated on up to the limit of the capacity of the tube; in this way, then, the current flowing through the head-phones is many times greater than where a two-coil loose coupler and the ordinary circuits are used.

How the Heterodyne Receiving Set Works.—In physics there is an apparatus called a *sonometer* which consists of a sounding-board on which two like strings are mounted. These strings can be tuned to vibrate at different frequencies by means of piano tension keys. Now, if you tune one of them so that it will make, say, 256 vibrations per second, and the other so that it will make 260 vibrations per second, and then set them to vibrating, the sound waves of the two different frequencies will interfere and will augment each other four times every second and you will hear them as beats.

In the same way if you have two oscillation circuits coupled together and set up oscillations of slightly different frequencies, say in one 1,000,000 oscillations per second¹ and in the other 1,001,000 oscillations per second, and this is easy to do by tuning the circuits with your coil, or condensers, or both, they will aug-

¹ This will give you a wave length of 300 meters.

ment each other 1,000 times per second. Now by connecting a detector and head-phones to the circuit and listen-in you will hear a musical note produced by the beats.

Such a beat, or heterodyne receptor as it is called, is extremely sensitive to feeble incoming waves, provided these are sent out by either a spark telegraph transmitter or by an arc or a vacuum tube oscillator where these are broken up by a chopper. It is not suitable for receiving either speech or music.

CHAPTER IV

VACUUM TUBE TRANSMITTING SETS

Not only can the vacuum tube be used as a detector and an amplifier for receiving sets, but it can be used as an *oscillator*, that is, a generator for setting up sustained oscillations and, hence, for sending out continuous waves. A vacuum tube oscillator can be used for sending either telegraph signals or telephone messages and music.

As a telegraph transmitter the vacuum tube oscillator will send farther than a spark-gap transmitter of the same power and, moreover, it will give better results than the latter when used for sending amateur wave lengths, that is, 200 meter waves and under. Finally there is very little more to a tube transmitter than there is to a spark-gap set, and it is just as easy to adjust and to work as the latter.

A vacuum tube telephone transmitter is built on exactly the same lines as the telegraph set, but where alternating current is used as the initial source of power the current must be *rectified*, that is, changed into direct current; since the latter is pulsating it must be further smoothed out by filters formed of reactance coils and condensers. Then, instead of using a telegraph key to modulate the sustained oscillations, so that dots and dashes will be sent out, a *microphone*, or *telephone transmitter*, as it is usually called, is employed just as it is in wire telephony.

The Vacuum Tube Oscillator.—A vacuum tube oscillator, for setting up oscillations, and which in turn radiates continuous

waves, is made exactly like the vacuum tube detector and amplifier; that is to say, it has a filament, a grid and a plate and, indeed, a detector tube, or better an amplifier tube, can be used as an oscillator as I mentioned in Chapter II, Part IV, where one of these served as a generator of oscillations for the heterodyne receptor, while an oscillator tube, or *power tube*, as it is sometimes called, can be used as an amplifier.

It is, therefore, perfectly possible to construct small continuous wave telegraph and telephone transmitting sets by using an amplifier tube as an oscillator, but to be able to transmit either signals or speech or music over any considerable distance you have got to put (1) power into your tube, and (2) have a tube that will stand up under the power. For this reason you should get an oscillator tube made especially for generating oscillations and these are made in several sizes which will be described presently.

The greatest difficulty the amateur has to contend with in installing a continuous wave telegraph or telephone transmitter is the high voltage necessary for energizing the oscillator plate. While a $22\frac{1}{2}$ volt dry battery will serve for a detector or an amplifier nothing less than a plate potential of 100 volts will do for even a demonstrating transmitter, while to send over any effective range you need a plate potential of at least 350 volts for the smallest oscillator tube made and 1,000 volts for the next size.

Generators of High Voltage Plate Currents.—For a simple demonstration continuous wave telegraph or telephone transmitter you can use (1) an *A* or storage battery for heating the filament of the oscillator tube and a 100 volt *B* or dry battery for energizing the plate; or better, (2) you can use 110-volt direct current from a lighting circuit for the plate. To cover distance, though, with a telegraph transmitter you can (3) step up a 110-volt alternating lighting current to 350 or 1,000 volts alternating current with a power transformer, but for a telephone transmitter you will either have to (4) convert a 110-volt direct current or an alternating current into 350 or 1,000 volts direct current by means of a motor-generator set, or (5) transform a 110-volt alternating

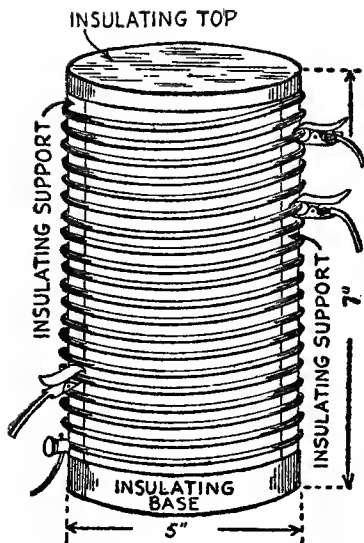
lighting current into 350 or 1,000 volts alternating current by a power transformer and then rectify this by means of a rectifier tube so that a pulsating direct current is obtained.

A Simple Demonstration Continuous Wave Telegraph Transmitter—*The Parts.*—This transmitter is suitable for setting up continuous oscillations on a small scale, and hence its range is very limited. It consists of (1) a *tuning inductance coil* formed of 20 turns of No. 5, 6, or 7 copper wire wound on an insulating tube with a binding post on one end and three adjustable taps on as many different turns as shown at *A* in *Fig. 186*.

Get (2) a vacuum tube amplifier that will take from 40 to 100 volts on the plate; (3) a *10-volt storage battery* for heating the filament, (4) a *100-volt dry battery* for energizing the plate, or use the current from a 110-volt direct lighting circuit; (5) four *.001 mfd. fixed condensers*; (6) a *5,000 ohm grid leak resistance* (see *B*); (7) a *choke coil* for preventing the oscillations that are set up by the tube from flowing back into the plate battery or the lighting circuit. This you can make by forming a core of soft iron wires $\frac{3}{8}$ inch in diameter and 2 inches long and winding on a dozen layers of No. 28 or 30 double cotton-covered or enameled magnet wire, and (8) an ordinary *telegraph key*.

How to Connect Up the Parts.—Begin by connecting the leading-in wire to one of the ends of the tuning coil; connect one of the sliding contacts with one end of the ground wire and the other end of this with one side of one of the condensers and lead the other side of the latter to a water-pipe or other ground. Now connect the aerial wire where it joins the tuning coil to one side of the second condenser and the other side of this to the grid of the oscillator tube.

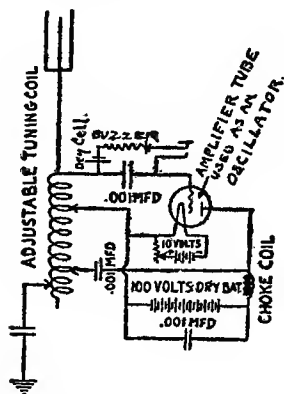
This done, connect the key, the buzzer and a dry cell up as shown at *C* in *Fig. 186*, then shunt them around the second condenser. Next connect one of the sliding contacts of the tuning coil with one terminal of the filament of the oscillator tube, the other terminal of the filament to the negative electrode of the *A* or storage battery, the positive electrode of this to one post of the rheostat and the other post of the latter to the other



A, Demonstration Transmitting Tuning Coil.



B, A 5,000-Ohm Transmitting Grid Leak with Mid-Tap.



C, Demonstration Continuous Wave Wireless Telegraph.
 FIG. 186.—A DEMONSTRATION C. W. WIRELESS TELEGRAPH
 SENDING SET.

terminal of the filament. This done, connect the next sliding contact of the tuning coil with one side of the third condenser and the other side of this to the plate of the oscillator.

Now connect the negative, or zinc, tap of the *B* or dry-cell battery, or lead of the 110-volt direct current lighting circuit, to the filament terminal that is connected with the positive electrode of the *A* or storage battery; connect the positive or carbon tap of the *B* battery, or lead of the 110-volt circuit to one end of the choke coil and the other end of this to the plate. Finally shunt the fourth condenser around the *B* battery or connect it across the leads of the lighting circuit. The oscillator tube will begin to generate oscillations as soon as you press down on the key.

A Simple Demonstration Wireless Telephone Transmitter.

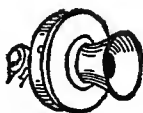
—As continuous waves are used for wireless telephony the parts of this transmitter are the same as those used for continuous wave wireless telegraphy. In a small wireless telephone transmitter, that is, where the oscillating currents are not larger than $\frac{1}{2}$ an ampere, the microphone can be connected in series with the aerial wire system. Connect up all the parts exactly as for the demonstration continuous wave telegraph transmitter but leave off the key and connect the microphone in the aerial instead. The microphone is shown at *A* in *Fig. 187* and a wiring diagram of the telephone transmitting set complete at *B*.

A 5-Watt Continuous Wave Telegraph Transmitter.—With a single 5-watt oscillator tube properly energized you can send telegraph signals to upwards of 100 miles and with two tubes in parallel you can cover a couple of hundred miles.

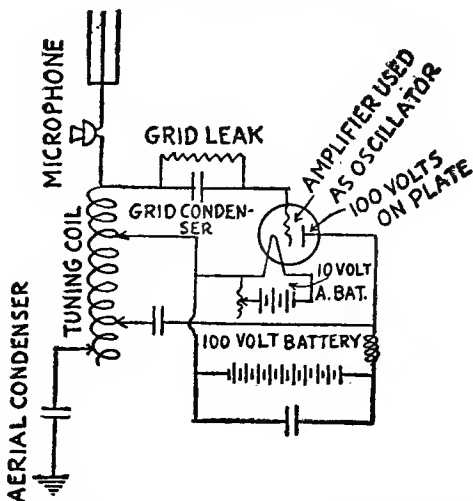
This 5-watt continuous wave telegraph transmitter is operated on 102.5 to 115 volt, 50 to 60 cycle alternating current with which most homes are now provided. To receive messages sent out by this transmitter either (1) a heterodyne receiving set (see Chapter II, Part IV), is needed, or (2) by using a *chopper* in the key circuit any crystal or vacuum tube detector receiving set will be able to get your signals.

The Parts You Need.—For this single-tube telegraph transmitter you will need (1) one 5-watt oscillator tube, with a socket;

(2) a power transformer; (3) a three-clip tuning inductance coil; (4) two by-pass condensers; (5) one grid condenser; (6) one grid leak resistance; (7) one aerial condenser; (8) two choke coils; (9) one telegraph key; (10) one hot wire ammeter, and (11) one alternating current voltmeter. The total cost of the above apparatus will be



A, Microphone Transmitter.

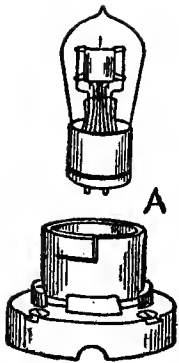


B, Wiring Diagram of the Demonstration Wireless Telephone.

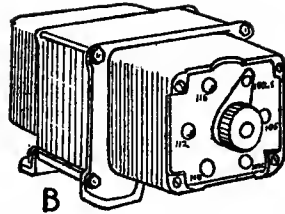
FIG. 187.—A DEMONSTRATION WIRELESS TELEPHONE SENDING SET.

in the neighborhood of \$75 without the meters and these will cost about \$25 more.

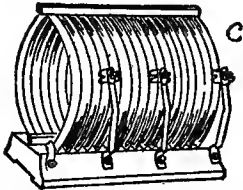
The 5-Watt Oscillator or Power Tube.—This power tube is made exactly like an amplifier tube only on a larger scale. It takes a current of 10 volts to heat the filament and 350 volts to keep the plate energized. The socket used with this tube is made of porcelain and has four taps. They are shown at *A* in *Fig. 188*.



A, The Oscillator Tube and Socket.



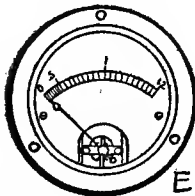
B, Alternating Current Power Transformer.



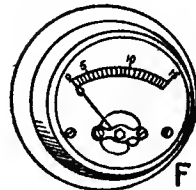
C, Three-Clip Transmitter Tuning Coil.



D, Adjustable Aerial Condenser.



E, A Hot-Wire Ammeter for the Aerial System.



F, A Voltmeter for the Filament Circuit.

FIG. 188.—PARTS OF A 5- TO 50-WATT C. W. WIRELESS TELEGRAPH SENDING SET.

The Alternating Current Power Transformer.—This power transformer is designed to be used with one or more 5-watt oscillator tubes. It has a primary coil wound on an iron core and two secondary coils. The primary is wound to take current from a 50 to 60 cycle source at 102.5 to 115 volts so that you can connect it up direct to your lighting circuit. One of the secondary coils delivers a 10-volt current for heating the filament and the other secondary coil delivers a 350-volt current for energizing the plate. The transformer is shown at *B*.

The Tuning Inductance Coil.—Instead of using a loose coupled oscillation transformer for receiving, the transmitting tuning inductance coil is close coupled, or *conductively coupled* as it is called, that is, the secondary coil is a continuation of the primary coil. It is formed of 25 turns of copper strip about $\frac{1}{8}$ of an inch thick and $\frac{3}{8}$ inch wide and is mounted horizontally on a wood base. It has three adjustable clips and a tap fixed to one end and is pictured at *C*.

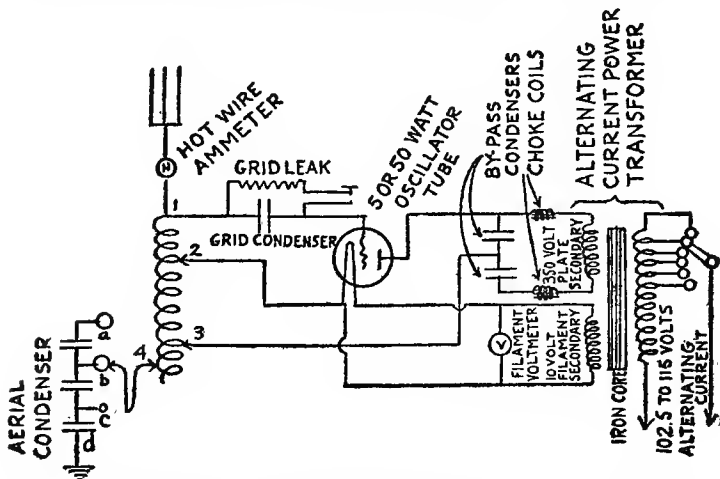
The Aërial Series Condenser.—This is a fixed condenser and has four taps as shown at *D*. It gives three different capacitances, namely, .0003, .0004, and .0005 microfarads, according to the way you connect it up, and it will stand up under a pressure of 7,500 volts.

The Grid and By-Pass Condensers.—These are plain fixed condensers, of .001 mfd. capacitance, and one is placed in the grid circuit with the key shunted around it and the other two are connected across the terminals of the plate secondary coil of the power transformer.

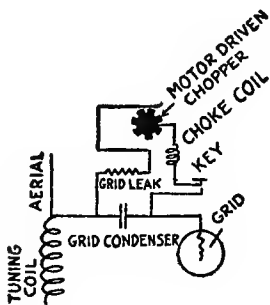
Transmitting Grid Leak.—This consists of a resistance of 5,000 ohms with a mid tap so that you can cut down the resistance to 2,500 ohms. It consists of a high resistance wire wound on a beat resisting insulator. It is shown at *B* in *Fig. 186*.

The Choke Coils.—These are used to keep the oscillations set up by the oscillator tube from surging back through the secondary coil of the power transformer. You can make these coils by winding about 90 turns of No. 30, Brown and Sharpe gauge, cotton covered insulated magnet wire on a tube 2 inches in diameter and $2\frac{1}{4}$ inches long.

The Meters.—A hot-wire ammeter, see *E*, in *Fig. 188*, reading from 0 to 2.5 amperes in the aerial is necessary so that you can see



A, Wiring Diagram for a 5- or 50-Watt Continuous Wave Telegraph Sending Set.



B, How the Chopper is Connected In.



C, A 50-Watt Oscillator Tube.

FIG. 189.—WIRING DIAGRAM OF A 5- TO 50-WATT WIRELESS TELEGRAPH SENDING SET.

when the circuits are in tune. When the meter gives the highest reading you will know that the circuits are tuned to each other, as well as the amount of energy that is being radiated. A volt-

meter, reading from 0 to 15 volts, as shown at *F* in *Fig. 188*, is needed to show when the voltage of the filament is right and this should be 7.5 volts.

How to Connect Up the 5-Watt C. W. Telegraph Transmitter.—To hook up the parts begin by connecting your aerial to the hot-wire ammeter and this to the end tap of your tuning coil, marked 1 in the wiring diagram shown at *A* in *Fig. 189*. Connect tap 4 with one of the ends of the aerial condenser marked *a*, *b*, or *c*, depending on the amount of capacitance you want in the circuit, and then connect the end of the condenser marked *d* to the ground.

Now connect tap 1 of the tuning coil to one side of the grid condenser and the other side of this to the grid, connect one end of the grid leak to one of the posts of the key, and then shunt these around the grid condenser. This done, connect tap 2 of the tuning coil to one of the terminals of the oscillator tube filament; from this juncture bring down a lead and connect it to one end of the 10-volt secondary coil of the power transformer and connect the other end of this secondary to the other terminal of the oscillator tube filament. Then shunt your filament voltmeter across the ends of the filament secondary coil.

You are ready now to connect the plate of the oscillator tube to one end of the choke coil and connect the other end of this to one of the ends of the 350-volt secondary coil of the power transformer; connect the other end of the latter to one end of the other choke coil and the other end of this to one side of one of the by-pass condensers. Then connect the other side of the latter with one side of the second by-pass condenser and the opposite side of this to the lead that joins the first choke coil with the plate of the oscillator tube between these two elements; this done connect tap 3 of the tuning coil in between the two by-pass condensers.

Finally connect the ends of the primary of the power transformer with the alternating current service wires and you are ready to send out continuous wave telegraph signals, but in order for a receiving station to get them it will have to be equipped with a heterodyne receiving set.

A Grid Chopper for the Above C. W. Telegraph Transmitter.

—In order for *any* receiving set to get signals from the continuous wave telegraph transmitter I have just described, you will have to put a grid chopper in circuit with the key and grid leak as shown in the wiring diagram at *B* in *Fig. 189*. A grid chopper is really a motor-driven rotary interrupter and breaks up the sustained oscillations so that wave trains are set up which are very much like those produced by a spark telegraph set.

A 50-Watt C. W. Wireless Telegraph Transmitter.—A single 50-watt oscillator tube will deliver enough energy to the aerial so that you can send telegraph signals 500 miles or so while with two 50-watt tubes in parallel you can cover distances of 1,000 miles and over. Like the 5-watt continuous wave telegraph transmitter these 50-watt sets operate on an initial alternating current of 102.5 to 115 volts at 50 to 60 cycles.

The Parts You Need.—The parts of this transmitter and the connections are identical with the 5-watt transmitter described above, except that the former are designed and built for utilizing a larger amount of current and transforming it into higher voltages.

The 50-Watt Oscillator Tube.—This tube is made just like the 5-watt tube only larger and of a little different shape, as shown at *C* in *Fig. 189*, and it takes 10 volts to heat the filament while 1,000 volts are needed to energize the plate. A porcelain socket is also used with this tube.

The Alternating Current Transformer.—For a 50-watt oscillator tube you will need a power transformer that has an input of 750¹ watts. The filament secondary coil delivers 10.5 volts between the ends of it while the plate secondary coil delivers 3,000 volts between its ends. This transformer will supply enough current for two 50-watt tubes. In all other respects it is like the one I described for the 5-watt power tube.

The Oscillation Choke Coils.—You can make these by winding about 260 turns of No. 30 Brown and Sharpe gauge cotton-covered magnet wire on a paper or glass tube 2½ inches in diameter and 3½ inches long.

Other Parts of the Transmitter.—The key, by-pass condenser, grid condenser and aerial condensers are exactly the same

¹ There are 746 watts in 1 horsepower, and 1,000 watts equal 1 kilowatt.

as those I described for the 5-watt transmitter, except that the grid leak is made a little larger to take more current, but it has the same resistance. The hot wire ammeter for the aerial wire should read from 0 to 5 amperes and the volt-meter from 0 to 15 volts. These parts are connected up as shown in the wiring diagram at *A, Fig. 189*. You can use a grid chopper with it (see *B, Fig. 189*), or not, depending on whether the receiving station has a heterodyne receptor or an ordinary receptor.

A 5-Watt Wireless Telephone Transmitter.—This wireless telephone transmitter is the simplest type I know of in which an oscillator tube is used to set up sustained oscillations as in the preceding telegraph transmitters. The plate, though, must be energized by a direct current of 350 volts and this can be had from either a *motor-generator*¹ or by means of an alternating current power transformer, the secondary current of which is converted into a suitable direct current by a *rectifier vacuum tube*. The oscillations in the aerial are varied, or *modulated*, as it is called, by a *microphone* and a *magnetic modulator* which I shall explain presently. It will send speech or music to a distance of, say, 25 miles.

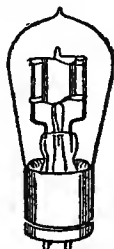
The Parts of a 5-Watt Wireless Telephone Transmitter.—For this transmitting set you will need: (1) a *tuning inductance coil*; (2) an *aerial condenser*; (3) a *grid condenser*; (4) *grid leak*; (5) two *5-watt oscillator tubes*; (6) two *20-watt rectifier tubes*; (7) a *blocking condenser*; (8) two *filter condensers*; (9) an *oscillation choke coil*; (10) a *filter reactor*; (11) a *110-volt alternating current power transformer*; (12) an *a. c. filament volt-meter*; (13) an *aerial hot-wire ammeter*; (14) a *6-volt dry or storage battery* for the microphone; (15) a *microphone*; (16) a *magnetic modulator*, and (17) a *switch* for the microphone circuit.

The 110-Volt Alternating Current Power Transformer.—Although the power transformer used for the continuous wave telegraph transmitters described in this chapter has three secondary coils, I mentioned only *two*, as these are the only ones used, but for a wireless telephone transmitter the third secondary coil is connected to a *rectifier tube*. For a 5-watt telephone transmitter

¹ This consists of a motor driven by 160 volt d. c. or a. c. current direct connected to the shaft of a 350 or 1,000 volt d. c. generator.

get a power transformer with an input of 325 volts. This is shown at *B* in *Fig. 188*.

The Rectifier Vacuum Tube.—This is a two-electrode vacuum tube (see *A* in *Fig. 190*) and it is used to convert alternating cur-

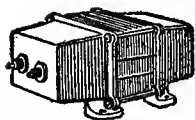


THE RECTIFIER TUBE

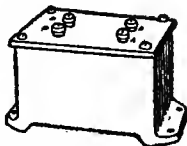


THE SOCKET

A, Two-Element Rectifier Tube.



B, The Filter Reactor.



C, The Microphone Magnetic Modulator.

FIG. 190.—PARTS OF A 5- TO 50-WATT WIRELESS TELEPHONE SENDING SET.

rent into pulsating direct current. These *rectifier tubes*, or *rectifier valves*, as they are sometimes called, are made so that they will take care of large currents. The rectifier tube you will need for a 5-watt oscillator tube transmitter is rated at 20 watts. It is shown at *A* in *Fig. 190*.

The Filter Reactor.—The purpose of a *filter reactor* is to

smooth out the pulsating direct current after it is produced by the rectifier tube. This consists of a large inductance and a number of condensers. A 160-milliampere filter reactor (see *B, Fig. 190*) is the kind you want for a 5-watt tube transmitter.

The Filter and Blocking Condensers.—All of these are fixed condensers having a capacitance of 1 microfarad each and they are made to withstand potentials of 750 volts.

The Microphone.—This is an ordinary carbon telephone transmitter as shown at *A* in *Fig. 187*. It can be mounted on a handle, a stand, or an extension bracket, but in any case the diaphragm must be kept in a vertical position to get the best results.

The Microphone Battery.—This can be either four dry cells or a 6-volt storage battery. The latter is the best, since the current does not keep dropping off.

The Microphone Modulator.—This is the best scheme for modulating the sustained oscillations set up in an aerial where one or more small oscillator tubes are used. It provides a means for coupling a microphone to the oscillation circuits and does not distort the sound waves which are impressed on the diaphragm (see *C, Fig. 190*).

Other Parts of the Transmitter.—The tuning inductance coil, the aerial condenser, the grid condenser, grid leak, oscillation tube, filter condensers, choke coil, filament volt-meter and aerial hot-wire ammeter are exactly the same as those described in connection with the 5-watt telegraph transmitting set.

How the Parts Are Connected Up.—Begin by connecting the aerial wire to the end tap of the tuning coil marked 1 in the wiring diagram shown in *Fig. 191*. Connect the adjustable tap 4 with one of the sides of the aerial condenser marked *a, b, or c*, depending on the amount of capacitance you want in it; then connect the side of the condenser marked *d* to one of the secondary posts of the magnetic modulator and the other secondary post of this with the ground. Connect the microphone, the 6-volt battery, the switch and the primary coil of the magnetic modulator in series.

This part of the system wired up, connect tap 1 of the tuning

coil to one side of the grid condenser and the other side of this to the grids of the oscillator tube; then shunt the grid leak around the condenser. Next connect tap 2 of the tuning coil to one of the terminals of the oscillator tube filament and from this bring a lead and connect it to one end of the 10-volt filament secondary coil of the power transformer and connect the other end of the filament to the other end of the filament secondary coil.

Now connect the ends of the filaments of the rectifier tubes to the ends of the 7.5 volt secondary coil of the power transformer. You are ready now to connect the plates of the oscillator tubes to one end of the oscillation choke coil and bring a lead from the other end of this to one side of the blocking condenser; connect the other side of this with one of the posts of the filter reactor and the power transformer and connect the other end of the filament to the other end of the filament secondary coil.

This done, connect one of the plates of the rectifier tubes to one end of the 550-volt secondary of the transformer which is the middle coil, and the other plate of the other rectifier tube to the other end of this coil. Connect the filter reactor and the filter condensers to the mid-taps of the filament secondaries and connect one end of the filter reactor to the mid-taps of the rectifier secondary.

Now connect clip 3 of the tuning coil to one side of the blocking condenser and the other side of this to the oscillation choke coil and the latter to the mid-tap of the rectifier filament secondary; connect the movable switch contact of the primary of your power transformer to one of the 110-volt alternating current service wires and connect the other terminal of the primary with the other service wire. Your wireless telephone is ready now for a tryout.

CHAPTER V

HOW VACUUM TUBE TRANSMITTERS WORK

Like the spark gap and the arc lamp the vacuum tube will set up oscillating currents. Unlike the spark gap but like the arc lamp the vacuum tube sets up sustained oscillations which, in turn, send out continuous waves and these can be used for either telegraphy or telephony.

The Vacuum Tube as an Oscillator.—When the vacuum tube is used as an oscillator, that is, as a means for setting up oscillations, three coils must be used as in a regenerative receiving set, but instead of being loose coupled they must be close coupled, hence, the tuning coil is made of one continuous length of wire wound up into turns as shown at *A* in *Fig. 186*. The coil is divided into three parts by means of the adjustable clips.

The top part of the coil acts as the tickler, the middle part as the primary and the lower part as the secondary. As in the regenerative receiving tuning coil the tickler feeds back a portion of the oscillations that are generated by the tube to the grid and as in the case of an amplifying tube (see Chapter III, Part IV), this augments, or amplifies, the voltage that is impressed upon it by the source of current which, let us suppose for the sake of simplicity, is a battery.

There are any number of ways to hook up a vacuum tube oscillator with the other parts of the transmitter, but in the last analysis all of them, that is, if they are operative, amount to the same thing. Those I have given in the preceding chapter may be taken as typical of the best designed ones. To start the oscilla-

tions going in the tube, all you need to do is to switch on the plate current; this will at the same time energize the grid when it augments the oscillations that flow through the oscillation circuit which includes the middle or primary coil, the filament, plate and condenser (see *Fig. 192*).

Connecting in a Vacuum Tube Oscillator.—To get the proper relation between that part of the tuning coil which is connected with the plate and that part which is connected with the grid you must adjust the first and second clips. It is necessary to maintain a balance between the values of the inductance coils and the condensers, for where the former are small and the latter are large the oscillations that are set up may get very small or stop entirely. When this takes

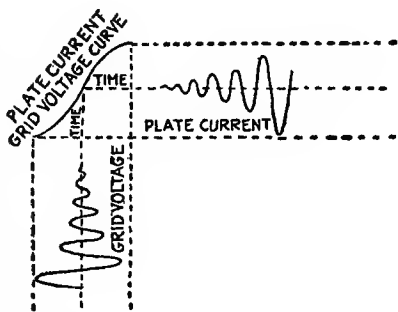


FIG. 192.—HOW THE OSCILLATIONS ARE FORMED IN THE OSCILLATOR TUBE.

place it is necessary to increase the inductance of the coils or decrease the capacitance of the condensers. By using the proper size coils and condensers the frequency can be made as high or as low as you want them within wide limits and, hence, you can send out waves of whatever length you want. The government regulation, however, fixes the maximum wave length for amateurs at 200 meters.

About High Power Oscillator Tubes.—To set up oscillating currents of high power two things are necessary and these are: (1) the tube must have a high vacuum, and (2) the plate must be energized by a high voltage. In the largest oscillator tubes that are made for amateur use to-day the plate is energized by a current of 2,000 volts and the plate current, that is the current that flows from the plate to the filament, is $\frac{1}{4}$ of an ampere and this gives a normal output of 250 watts or about $\frac{1}{3}$ of a horsepower.

A tube to stand up under this voltage and current must have a high vacuum and the higher this is the more readily will it set up oscillations and the longer will it last. To carry a large current the tube itself must be large and means must be provided for radiating the heat.

On the Use of Oscillator Tubes.—The temptation of most beginners is to force the oscillator tube to generate higher power oscillations than it was intended for; this they do by overloading it, that is, to increase the filament brightness and add to the voltage of the plate. Where more power is wanted a far safer and, in the end, a less expensive way is to connect two oscillation tubes in parallel and then cutting down the filament brilliancy a little.

When you have your transmitting set all hooked up and are ready to try it out for the first time do not apply more than half of the rated voltage to the filament and plate, until you find that you have all of the parts connected up O. K.; then you can heat the filament to brilliancy and give the plate its full voltage. To get the best service out of an oscillator tube and make it last the longest possible time you should connect a voltmeter across the terminals of the filament. By keeping the voltage at exactly the same value all the time you can extend the life of the tube to a very considerable extent.

CHAPTER IV

USEFUL INFORMATION

Government Rules and Regulations.—The time was, and not so very long ago, when a boy could own any kind of a wireless set, use any length of wave he wanted to and send messages wherever he pleased and no one could say him nay.

But things have changed in the last couple of years and while anyone can still receive wireless messages without having a license no one can send wireless messages without having first passed an examination and received a license from the Government.

There are three grades of licenses issued to amateurs by the Government and these are: (1) restricted amateur stations, (2) general amateur stations, and (3) special amateur stations. If you are a beginner, a restricted amateur license is the kind you want and this means that you can use a wave length of not more than 200 meters and a transformer having an input of $\frac{1}{2}$ a kilowatt.

The general amateur license permits you to use a wave length up to 200 meters just as the restricted amateur license does, but you can use an input of 1 kilowatt and, hence, send farther. Finally, the special amateur station license gives you the right to use wave lengths up to 375 meters and a transformer having an input of 1 kilowatt. In order to get this kind of a license you must have had at least two years' actual experience in wireless.

To get a license covering any of the above grades, you must write to the U. S. Radio Inspector who lives in your district. The following is a list of the districts and the city in the district where the Radio Inspector has his office. When you want to get a license simply address your letter to the U. S. Radio Inspector, Boston, Mass., or whatever the city is in your district where he

is located, and he will send you the proper blank forms to fill out. No fee or charge of any kind is made for an operator's license.

DISTRICTS	CITIES WHERE RADIO INSPECTORS ARE LOCATED
First District.....	Boston, Mass.
Second District.....	New York, N. Y.
Third District.....	Baltimore, Md.
Fourth District.....	Norfolk, Va.
Fifth District.....	New Orleans, La.
Sixth District.....	San Francisco, Cal.
Seventh District.....	Seattle, Wash.
Eighth District.....	Detroit, Mich.
Ninth District.....	Chicago, Ill.

Full information relating to all grades of licenses can be had by sending 15 cents to the Superintendent of the Government Printing Office, Washington, D. C., for a little book called *Radio Communication Laws of the U. S.*, and another called *International Radio Telegraph Convention*.

Summary.—Boiled down, then, the government will permit you to (1) receive messages without a license, but (a) you must keep secret all messages you receive, and (2) send messages after you have obtained a license, providing that (a) your wave length does not exceed 200 meters, and that (b) the input of your transformer is not more than 1 kilowatt.

Fees.—The government makes no charge for any operator or station license.

Rules and Requirements of the National Board of Fire Underwriters for Wireless Telegraph Apparatus.—The following Paragraphs are taken from the *National Electrical Code*, a copy of which may be had for the asking by addressing the National Board of Fire Underwriters, 135 William Street, New York City:

rules do not apply to wireless telegraph apparatus installed on ship-board.

In setting up wireless telegraph apparatus, all wiring within the building must conform to the general requirements of this Code for the class of work installed and the following additional specifications:

(a) Aërial conductors (wires) to be permanently and effectively grounded at all times when station is not in operation by a conductor not smaller than No. 4 Brown and Sharpe gauge copper wire, run in as direct line as possible to the water pipe at a point on the street side of all connections to said water pipe within the premises, or to some other equally satisfactory earth connection.

(b) Aërial conductors (wires) when grounded as above specified must be effectually cut off from all apparatus within the building.

(c) Or the aërial to (can) be permanently connected at all times to earth through a *short-gap lightning arrester*; said arrester to have a gap of not over .15 inch between brass or copper plates not less than $2\frac{1}{2}$ inches in length parallel to the gap and $1\frac{1}{2}$ inches the other way with a thickness of not less than $\frac{1}{8}$ inch mounted on non-combustible, non-absorptive insulating material of such dimensions as to give ample strength. Other approved arresters of equally low resistance and substantial construction may be used.

(d) In cases where the aërial is grounded as specified in paragraph (a) the switch employed to join the aërial to the ground connection shall not be smaller than a standard 100-ampere knife switch.

(e) Where current is obtained direct from the street service the circuit must be installed in approved metal conduits or armored cable. In order to protect the supply system from high potential surges, there must be inserted in the circuit either a transformer having a ratio which will have a potential on the secondary leads not to exceed 550 volts, or two condensers in series across the line, the connection between the said condensers to be permanently and effectually grounded. These condensers should have a capacity of not less than one-half *microfarad*.

List of Land and Ship Stations.—A list of land and ship stations of the United States, including amateurs, and giving call letters, wave lengths, nature of service, etc., can be had by sending 15 cents to the Superintendent of Documents, Government Printing Office, Washington, D. C.

APPENDICES

APPENDIX A

Brown and Sharpe Wire Gauge.—A wire gauge is not only used to find the sizes of wires, but to measure them as well. A wire gauge is a flat piece of steel cut in a circular form about $\frac{1}{10}$ inch thick and $2\frac{1}{4}$ inches in diameter. It has 36 slots cut in

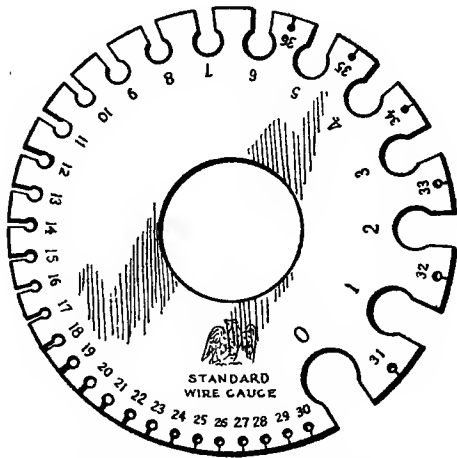


FIG. 193.—BROWN AND SHARPE WIRE GAUGE.

its edge and each slot is stamped with a number beginning with 5 and ending with 36; and each number is the size of the wire which fits into its respective slot. The holes at the end of the slot have nothing to do with the size of the wire. A cut of the *Brown and Sharpe gauge*, which is also called the *Standard*

Wire Gauge, is shown full size, so that you can roughly judge the number of any of the larger sized wires. Brown and Sharpe wire gauge is abbreviated B and S gauge; a B and S wire gauge costs about \$2.10.

APPENDIX B

Drills.—Drills for drilling holes in wood and metal are used with a drill stock. The drills are called twist drills, and the sizes of drills needed for doing the work set down in this book are:

No. of Drill	For Taps or Screws
38 For	4—36
32 For	6—32
28 For	8—32
22 For	10—24
13 For	12—24

The smaller drills cost about 5 or 6 cents each, and the larger drills cost about 10 or 12 cents each.

APPENDIX C

Taps and Dies.—*Taps* are for cutting inside threads, as in nuts, while *dies* are for cutting outside threads, as on screws. Taps are used in a wrench and dies are used in a stock. A set including the following sizes with wrench and stock in a box costs \$4.25.

No.	Threads to Inch
4	36
6	32
8	32
10	24
12	24

APPENDIX D

Screws and Nuts.—Machine screws and nuts run in the same sizes as taps and dies. The size is found with a Brown

and Sharpe standard screw gauge. When you ask for a 4—36 screw or a 4—36 tap you mean that you want a screw or a tap size No. 4 Brown and Sharpe screw gauge and which has 36 threads to the inch.

No.	Threads to Inch
4	36
6	32
8	32
10	24
12	24

APPENDIX E

Types of Aërials.—There are a number of types of aërials and the kind of an aërial you will put up will probably depend very largely on conditions. The very simplest type is the *vertical aërial*. The vertical aërial has very little capacity and is

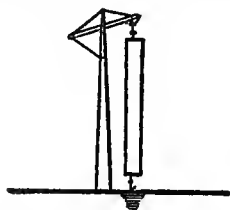


FIG. 194.—VERTICAL
AËRIAL.

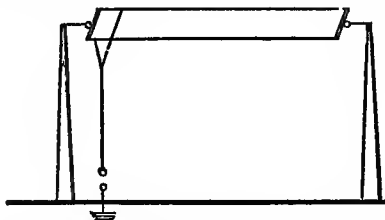


FIG. 195.—HORIZONTAL Γ (Inverted L)
AËRIAL.

now seldom used. The type described in Chapter III, Part II, is called a *horizontal* or *flat-top*, the first being called a *T aërial* for the reason that the leading-in wire is connected in the middle of the aërial and this makes it look somewhat like the capital letter T. The second form is the inverted L (Γ) aërial, the leading-in wire in this case being connected with the aërial at one end or the other. The horizontal aërial of either form is a much better radiator of electric waves than the vertical aërial, and is widely used. The horizontal aërial is the type used at the great Arlington Station. Another type is the *fan aërial*, of

which there are, likewise, two forms. In the first form the aërial is put up with all the wires insulated from the top of the pole

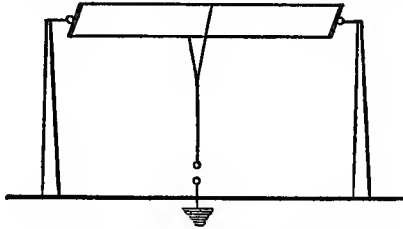


FIG. 196.—HORIZONTAL T AËRIAL.

and spreading out and down toward the ground. In the second form the wires are fastened to a wire or rope stretched between

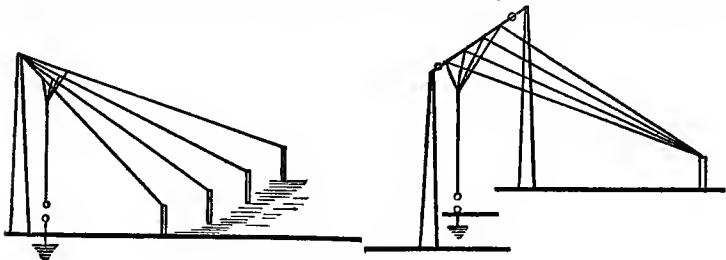


FIG. 197.—FAN AËRIAL.

two poles and are brought down to the ground in a single wire. A fan aërial is almost as good as a horizontal aërial, especially if

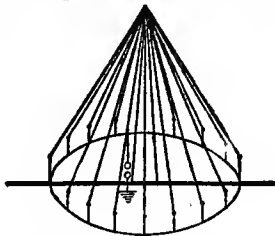


FIG. 198.—UMBRELLA AËRIAL.

a large number of wires are used. The fan aërial is the type used at the great Eiffel Tower Station in Paris. A modification

of the fan aërial is to spread out the wires all around the pole when it becomes an *umbrella aërial*. This makes a better aërial than any of the other types.

DEFINITIONS OF SOME WORDS AND TERMS USED IN THIS BOOK

- Abbreviations.** The shortening of words or sentences for wireless messages. For instance, instead of spelling out the whole message, "How do you receive me?" you simply send the letters Q R K, which also means "I am receiving well."
- Act of Congress of August 13, 1912.** Laws passed by Congress to regular wireless communication. See Part III, Chapter III, page 196.
- Acts.** Laws passed by Congress.
- Adjustable.** (1) to Change by steps. (2) A word interchangeably used with *varied*, as an *adjustable* resistance.
- Adjustable resistance.** A resistance which can be changed so that exactly the amount of current needed will flow through the circuit.
- Aërial.** See Appendix E.
- Aërial conductors.** Aërial wires.
- Aërial rope.** A rope fastened to the end of an aërial and brought down through a pulley block.
- Aërial wire system.** An aërial and ground wire and that part of an inductance coil which connects them.
- Affected.** To act upon or to be moved by.
- Alternate.** To change in direction.
- Amateur.** One who practices wireless for the fun and interest and not for the money there is in it.
- Ampere.** (1) The unit of current strength. (2) A fresh dry cell will develop from 15 to 20 amperes.
- Antenna.** An aërial.
- Arc across.** A continuous flame between the ends of the secondary coil of a transformer. An *arc* differs from a *spark*, which is a periodic luminous discharge.
- Arm.** A projecting piece of metal.
- Back center.** One of the two fixed points of a winding machine or lathe between which a spool or form is held and turned. The back center is the left-hand center; it is also called a *dead center*. The right-hand center is called a *live center*.
- Ball and socket joint.** A joint connecting the head band and ear-pieces of a telephone receiver so that they can be turned in almost any position.
- Bell wire.** No. 18 Brown and Sharpe gauge copper wire, double cotton-covered, parafined and colored so that when a number of wires are run together they can be told from each other without sorting them over.
- Bookbinder's cloth.** A kind of glazed cloth used for covering books, also for covering small induction coils.
- Broken.** When a circuit is not completed it is said to be *broken*.

- Call letters.** Letters by which ship and shore stations are known. Three letters are used for all Navy, Army and Commercial stations. The call letters of the Government Station at Arlington, Va., are N A A.
- Call signal.** The figures and letters by which your station is known. The call signal of your station is given you by the Government when you receive your license.
- Cell.** (1) A single element for producing a current, as a dry cell. (2) Two or more cells coupled together form a battery.
- Chalcopyrite.** Copper pyrites, a brass-colored mineral used as the sensitive element in crystal detectors. (See Zincite.)
- Closed.** When a circuit is completed, or made, by means of a key, interruptor, etc., the circuit is said to be *closed*.
- Cohere.** To draw together. When electric oscillations surge through a loose contact such as is formed by a steel needle resting on a pair of leads, the molecules of the steel and lead are drawn together, or *cohere*.
- Collar.** A ring or band of metal.
- Composition foil.** A low grade of tin foil made so by the addition of lead to the tin.
- Conductive coupling.** An aerial and a ground wire, forming an open circuit, and a closed circuit, which are connected together by a single inductance coil. Also termed a *direct coupling*.
- Contact point.** The spot where contact is made between two substances. The spot where a metal or a crystal touches another piece of metal or a crystal.
- Contact points.** Any two wires or electrodes which are used to make and break a current, as the *contact points* of an interruptor or the *contact points* of a key.
- Continuous.** Without a break.
- Contractile spring.** A spiral spring which draws together, or contracts, when the tension is removed.
- Conventional symbols.** A number of different marks, figures and signs which wireless workers have agreed to use to represent certain pieces of apparatus.
- Counter-sink.** An enlargement of a hole for a screw so that the head of a screw will set in flush with the surface.
- Crystal detector.** A detector in which crystals such as silicon, zincite, etc., are used as the sensitive element.
- Crystalline.** Pertaining to or like crystal.
- Cut-in.** To put more resistance, inductance or capacity in a circuit, as to *cut-in* a turn of wire.
- Cut-out.** To take some resistance, inductance or capacity out of a circuit, as to *cut-out* a Leyden jar.
- Cycle.** (1) A series of changes which when completed are again at the starting point. (2) A period of time at the end of which an alternating or an oscillating current repeats its original direction of flow.

- Damped out.** (1) The rate at which electric oscillations decrease or die out. (2) Electric oscillations are *damped out* by the resistance and the inductance of a circuit and the change of energy into electric waves.
- Determine.** To fix or to make, as the inductance of a circuit *determines* its *period* of oscillation.
- Device.** (1) An apparatus or instrument or part thereof. (2) Any arrangement for producing a required result.
- Die.** A steel block with teeth on its inner surface. It is used for cutting threads on rods, etc.
- Direct coupling.** An aerial and ground, forming an open circuit, and a closed circuit, which are connected together by a single inductance coil. Also termed a *conductive coupling*.
- Disk.** A thin, circular piece of metal or wood. A telephone diaphragm is a disk of sheet iron. The cheek of a coil is a disk of wood. A pie is a disk formed of wound-up wire.
- Eddy currents.** Electric currents set up in the core of a transformer by the currents flowing in the primary coil. These eddy currents waste the primary current by developing heat in the core. The way to prevent eddy currents is to make the coil of very thin strips of soft iron and then varnish the strips.
- Electric oscillations.** The same as high-frequency currents.
- Electric pressure.** The force that moves a current along a wire. It is called *electromotive force*. The *unit of electromotive force* is called a *volt*.
- Electric waves.** Waves in the *ether* sent out by electric oscillations in an aerial wire.
- Electrodes.** Usually the parts of an apparatus which dip into a liquid and carry a current. The *electrodes* of a battery are the zinc and carbon elements; the *electrodes* of an electrolytic interruptor are the copper rod, or platinum point and the lead plate; the *electrodes* of a spark-gap are the metal points or balls between which the sparks pass.
- Electrose insulator.** Insulators for aerial wires made of a patented compound having a high resistance and great strength.
- Energy.** The power of an electric current.
- Ether.** A substance filling all space and in, by and through which light, electricity and magnetism travels.
- Examination.** Testing the skill and knowledge of an operator by a wireless inspector to ascertain if he should be granted a license.
- Eye.** A hole in the ring of an insulator or a *with*.
- Factor.** One or more causes that produce an effect, as the capacity of an aerial wire is a factor in determining its wave length.
- Feebly damped oscillations.** High-frequency electric currents which swing, or oscillate,

- late, a large number of times before they die out.
- Feed.** To supply to; to furnish with.
- Finger.** A small strip of metal.
- Fixed condenser.** A condenser whose capacity cannot be changed.
- Flaming arc.** The continuous luminous discharge which takes place between the ends of the secondary coil of a transformer.
- Flat-top aerial.** See Appendix E.
- Flexible cord.** A number of very thin copper wires twisted together and having a silk or cotton covering woven about them so that it will bend easily. It is used for connecting a detector with a telephone receiver.
- Fools' gold.** Iron pyrites, a yellow mineral which glitters like gold. It is used in crystal detectors for the sensitive element.
- Free end.** All through this book you will find the term *free end* used. After a wire, or spring, or other piece of metal, is fastened at one end the other end is called the *free end*, at least until it is fastened to something else or something else is fastened to it.
- Full load.** Using as much current as the apparatus is designed to use. Said of a transformer when it is taking its full amount of current.
- Generator.** (1) A dynamo. (2) Any machine or apparatus which produces a current of electricity.
- Government rules and regulations.** See Part III, Chapter III, page 196.
- Ground clamp.** A clamp for making a good connection between the ground wire and a pipe.
- Guy out.** To fasten a pole or mast in position with ropes, called guy ropes.
- Hack saw.** A small saw used for sawing metals.
- Hard fiber.** An insulating material made of the pulp of paper which has been toughened and waterproofed by chemicals and hardened by pressure.
- Hard solder.** An alloy used by jewelers for soldering gold, silver and other metals; it only melts at red heat. It is melted by means of a blow-pipe.
- Head telephone receiver.** One or two *watch-case receivers* joined together with a metal or hard rubber band which fits over the head and holds the receivers closely to the ears.
- Helix.** (1) A tuning coil for sending. (2) A spiral of wire.
- High-frequency currents.** The same as electric oscillations.
- High potential surges.** Currents of high pressure which sometimes back up into the primary of the transformer and into the feed wires. Such surging currents will burn out the generator and do other damage unless devices are installed to prevent them.
- High-power station.** Stations using large amounts of

- power. The Government station at Arlington, Va., has a sending range of about 3,000 miles.
- High-pressure circuit.** The circuit of the secondary coil of an induction coil, or of a transformer. The pressure in these circuits may range from 5,000 to 300,000 volts.
- High-pressure current.** A current such as is usually produced by the secondary coil of an induction coil or a transformer or the discharge of a Leyden jar or glass plate condenser. A high-voltage current.
- High-pressure electricity.** Same as high-pressure current. A current such as is usually produced by the secondary of an induction coil or a transformer or a Leyden jar.
- Horizontal aerial.** See Appendix E.
- Horse-power.** One horse-power equals 33,000 pounds, raised 1 foot in 1 minute.
- Incoming waves.** Electric waves which impinge or strike the aerial of a station.
- Jump sparks.** Electric discharges produced by an induction coil or a condenser.
- Lead.** (1) To carry a wire to.
(2) A wire carrying a current.
- Lever.** A bar of metal which moves freely on a fixed point.
- License.** Permission given by the Government to a person to operate a wireless station.
- Licensed operator.** A wireless operator who is licensed to operate a station.
- Lines of Magnetic Force.** Curved lines of force extending from one pole of a magnet to the other. If a magnet is placed under a sheet of glass or a heavy sheet of paper and fine soft iron filings are sprinkled over the glass or paper the filings will move about and form themselves into curved lines which show the lines of magnetic force.
- Linking.** Joining together.
- List of land and shore stations.** Published by the U. S. Government. A list of wireless telegraph stations of the U. S. The edition of 1915 gives the names of all the ship and shore stations, their call signals and the wave lengths which they use. It also gives the names of all the boys and amateurs who own licensed stations, the location of their stations, their call signals and the power in *watts* which they use. Send 15 cents to the Superintendent of Documents, Washington, D. C., and he will send you a copy.
- Listening-in.** Listening to wireless messages.
- Loose contact.** Contact between conductors without pressure. When a steel needle is laid across the leads of a detector a *loose contact* is formed which is sensitive to electric oscillations.
- Low-pressure circuit.** The circuits of the generator and primary coil of an induction coil or a transformer. The pressure in these circuits may range from 110 to 220 volts.

Low resistance. Having little resistance.

Made. When a circuit is completed by means of a key, interruptor, contact of wires, or spark-gap the circuit is said to be *made*.

Magnetic force. The magnetizing power of a current in the magnet coils.

Mains. The wires which carry the current from the street service into the house.

Masthead. The top or highest point of a wireless pole or mast.

Meter. A meter is 39.39 inches long.

Mica. A transparent mineral, sometimes called isinglass, which can be split into very thin sheets. It is a very good insulator and is largely used in making condensers.

Microfarad. The $\frac{1}{1000000}$ of a *farad*.

National Board of Fire Underwriters. A Board organized to enforce such rules and regulations as the Electrical Committee of the National Fire Protective Association may recommend. See Book III, Chapter III, page 199.

National Electrical code. The rules and requirements laid down by the *National Board of Fire Underwriters*.

Nautical mile. A nautical, or sea, mile is 6,087 feet. A statute, that is a legal, or ordinary mile in the United States, is 5,280 feet.

Non-absorptive. A substance which will not absorb water.

Non-combustible. A substance which will not burn.

Ohm. The unit of resistance. The resistance of 400 feet of common telegraph wire is about *one ohm*.

Open. When a circuit is not completed or is broken, it is said to be *open*.

Open key. When a circuit is broken by means of a key, the key is said to be *open*.

Oppose. To offer resistance.

Oscillating currents. Currents which surge with high frequency in open or closed circuits.

Oscillation. (1) The swing of a pendulum. (2) The swing of a high-frequency current. (3) A train of electric *oscillations* set up by a single spark.

Out-going waves. Electric waves which are emitted or sent out by the aerial of a station.

Parallel. When all the zines of a battery are connected together and all of the carbons are connected together, the battery is said to be connected in parallel.

Period. The length of time it takes a pendulum or an electric oscillation to make a complete swing.

Power switch. A switch placed in the circuit formed by the generator and the primary of the transformer.

Principles. The first causes that produce results.

Process. The way of working, the course of procedure.

Quick break. A quick separation of the contact points of

- an interruptor. A quick separation of an electric circuit. A *quick break* and the number of breaks per minute which an interruptor makes are entirely different things, but both are needed for the proper working of an induction coil.
- Radiated.** Sent out, as electric waves are *radiated* from an aerial wire.
- Radio.** Wireless. The word *radio* was adopted by the International Radio Telegraphic Convention to take the place of the word wireless. Wireless and *radio* mean exactly the same thing.
- Radio Communication Laws of the United States.** See Part III, Chapter III, page 196.
- Ream.** To enlarge a hole.
- Reamer.** A tool for enlarging holes.
- Rectified.** To change an oscillating current into a direct current. Oscillating currents are *rectified* or changed into direct currents by crystal detectors.
- Resistance.** The friction offered by a wire or other conductor to the passage of a current.
- Respond.** To act when a force is applied, as a detector responds to the action of electric oscillations.
- Reversal.** Change of the direction of the flow of a current.
- Revolving element.** The spool, or form, including the spindle on which it is fixed in a winding machine.
- Roughly tuned.** To be tuned nearly enough for practical purposes.
- Satisfy.** To fulfill all the required conditions.
- Scale.** Spaces or divisions marked off for the purpose of measurement, or comparison, as the scale of a hot-wire ammeter.
- Sending helix.** A tuning coil for sending.
- Sensitive.** Affected by a very small current. A detector is sensitive when it will respond to oscillations of one $\frac{1}{1000}$ of an *erg*.
- Series.** When the zinc of one cell is connected to the carbon of another cell the battery thus formed is said to be connected in series.
- Shank.** (1) The part of a bolt between the threaded end and the head. (2) The part of a leading-in insulator next to the shoulder.
- Shoulder.** (1) The bulging part of a leading-in insulator which sets up against the window pane. (2) An offset for keeping a thing in place.
- Silicon.** A chemical element used in crystal detectors for the sensitive element. It is one of the most sensitive of the rectifying crystals.
- Slider.** A piece of metal which slides along rods or other guides and which carries a contact spring.
- Slot.** A slit or narrow cut in a piece of metal, as a slot in a screw head.
- Soft-drawn wire.** Wire which is not made springy during the process of making. This kind of wire is easily handled when making aërials.

Source of current. A battery or any kind of a generator of electric currents.

Specifications. The definite statement of requirements of the *National Board of Fire Underwriters* for installing wireless stations. These are included in the *National Electrical code*.

Static. Atmospheric electricity which charges the aerial and discharges through the detector. When the *static* is strong close your lightning switch.

Stem. A slender cylindrical piece of metal.

Stepping-up. Increasing the pressure of a current, as an induction coil, or a transformer *steps-up* the pressure of a current.

Stranded wire. Aerial wire made up of a number of small wires twisted together.

Strongly damped oscillations. High-frequency electric currents which make only a few swings, or oscillations before they die out.

Succession. Following each other at regular intervals.

Support. A piece of wood or metal which holds something in place.

Surging. Moving to and fro; oscillating. Said of high-frequency currents in a circuit.

T aerial. See Appendix E.

Tap. A tool for cutting inside threads.

Taper. Smaller at one end than at the other.

Taut. To stretch tight, as a taut aerial.

Telephone cord. See *Flexible cord*.

Thread. (1) The tooth of a screw. (2) To cut threads on a rod with a die. (3) To thread a nut.

Thumb screw. A screw or nut having wings on it so that it can be tightened or loosened with the thumb and fingers.

Trains of waves. Electric waves which follow each other at regular intervals. Each electric oscillation sends out an electric wave and, hence, as several oscillations take place before all the energy is damped out, an equal number of electric waves will be sent out. This forms a *train of waves*.

Transferred. The energy of a current flowing in a primary circuit or coil which is changed over to current which is set up in the secondary coil or circuit. This *transfer* of energy takes place by induction.

Tune in. To *tune* a receptor so that the signals from the station wanted are the loudest.

Tune out. To *tune* a receptor so that the signals of all stations not wanted are weakest.

Tuned closed circuit. (1) A circuit formed of a condenser, inductance coil and a spark-gap for a transmitter. (2) A circuit formed of a condenser, inductance coil and a detector for a receptor.

Tuned open circuit. A tuned aerial wire system.

Variable. To change gradually, as a variable condenser.

Variable condenser. A con-

denser whose capacity can be changed.

Variable resistance. A device for regulating a current flowing in a circuit, as a water resistance in the primary circuit, or a potentiometer in the receiving circuit.

Vibrate. To move to and fro rapidly, as the diaphragm of a telephone receiver; to swing; to oscillate.

Volt. The unit of electric pressure, or electromotive force as it is called. A dry cell will develop from $1\frac{1}{2}$ to 2 volts.

Washer. A small flat metal ring placed on a screw between the head or below a nut to serve as a cushion. Where a connection is to be made with a screw two washers are slipped on the screw, and the wire is looped around the screw between them.

Watt. (1) The unit of work done by a current. (2) One ampere \times one volt = one watt. (3) 746 watts = one horse-power. (4) a dry cell giving 20 amperes at $1\frac{1}{2}$ volts will develop $24\frac{1}{2}$ of a horse-power.

Wire up. (1) To connect all the parts of an apparatus

with wire. (2) To complete all necessary circuits.

Wireless code. (1) The International Morse code. (2) The alphabet arranged in dots and dashes. (3) A modification of the regular Morse code.

Wireless eye. A fanciful name given to detectors, since detectors sense electric waves which are too long for the eye to see through the electric oscillations which are set up.

Wireless key. A device for making and breaking up a current into dots and dashes. A key for wireless work usually has larger contacts than an ordinary telegraph key.

Wireless waves. (1) Electric waves. (2) The waves sent out through space by oscillating currents in an aerial wire.

Work. To energize, to operate, as to work a transformer.

Zincite. A deep red mineral crystal. It is used in crystal detectors as a sensitive element. Zincite is very sensitive to electric oscillations when in contact with *chalcopyrite*.

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